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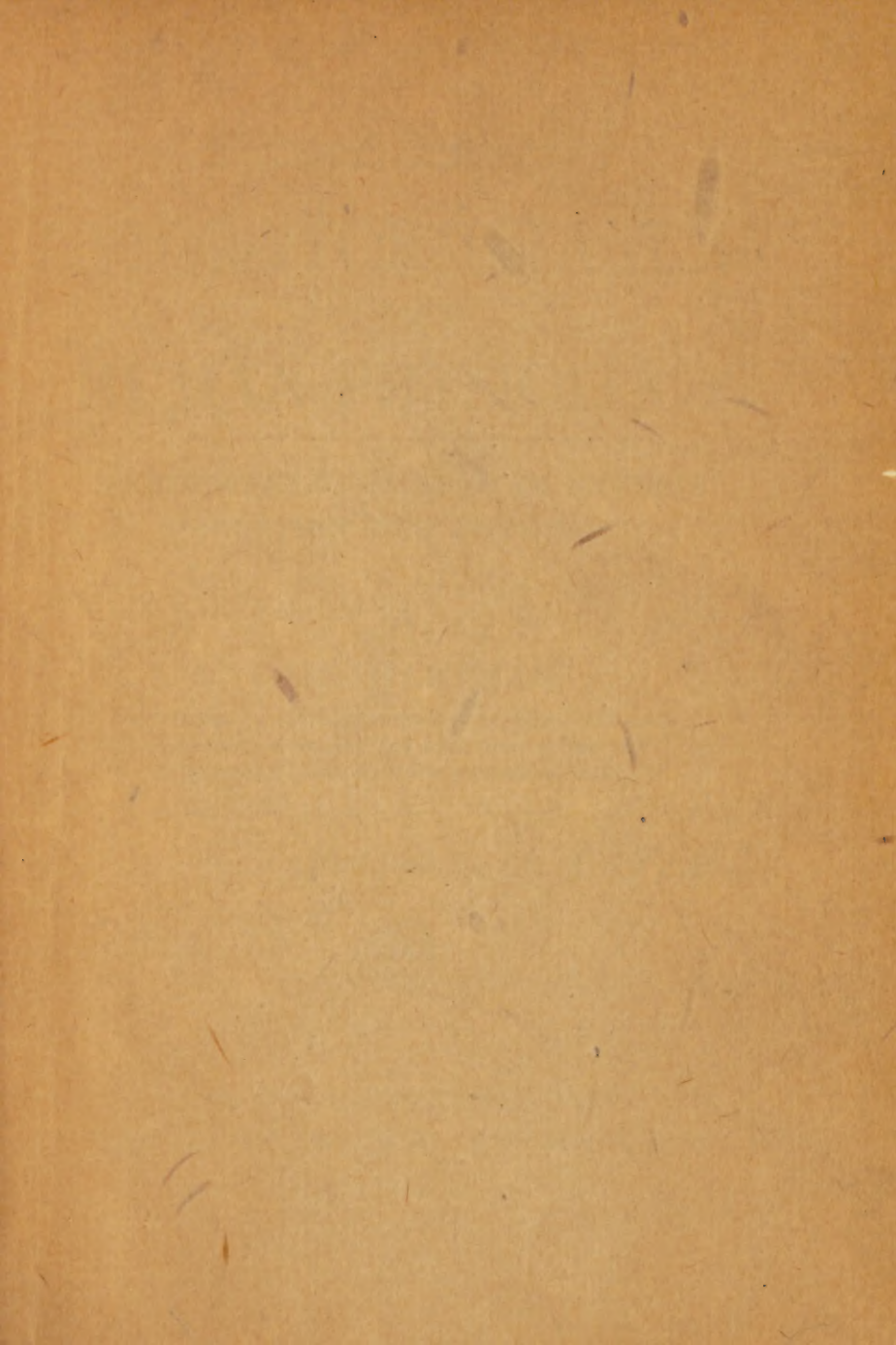
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NEW-WORLD SCIENCE SERIES

LABORATORY MANUAL

for

HUMAN PHYSIOLOGY

EXPERIMENTAL STUDIES IN HYGIENE
SANITATION AND PHYSIOLOGY

✓ BY
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PREFACE

THE work prescribed in this manual, which has been specially prepared for use with Ritchie's Human Physiology, is as simple as it is possible to make it and the directions are so detailed that any teacher can carry out most of the experiments. The size of the volume is due to the detailed description of the experiments rather than to their number.

In favorable conditions, most of this work can be gone through in a half-year. The teacher must judge of this for himself and, if pressed for time, make a selection from the experiments given. If the course is taken as the first of the sciences studied in the first year of the high school, less can, of course, be done than in the higher grades in the same length of time.

The apparatus and materials required for the greater number of these experiments are comparatively inexpensive and in many cases suggestions are given for cheaper substitutes. These, with a little ingenuity and care, may be made or procured by the teachers or pupils themselves, a specially helpful feature for smaller schools and schools in rural districts.

Special attention is called to the chapter How to Use this Manual at the beginning and to the list of apparatus, material, formulæ, etc., at the end of the book.

Thanks are due to Professor John W. Ritchie for his helpful suggestions and practical advice in the preparation of the work.

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HOW TO USE THIS MANUAL

THE difficulties of overcrowded classes, insufficient laboratory equipment, and limited time given to the subject have here been fully considered. The arrangement and presentation of matter have been made with the view of helping the teacher to furnish the student as much first-hand knowledge of Physiology and Hygiene as possible in the existing conditions in the great majority of high schools.

The laboratory method. Mere book knowledge of a science can rarely become a vital possession, just as the impressions received from reading a description of a circus cannot be as lasting nor as realistic as those received from a single visit. Therefore, as many exercises as possible should be done by the pupil himself.

Three kinds of laboratory exercises. The exercises outlined in this manual are of three kinds,—*Demonstration*: those demonstrated by the teacher or by some one appointed by him; *Class work*: experiments by the pupils under the teacher's direction; and *Home work*: experiments performed without the teacher's direction. This apportionment of the experiments is, however, merely suggestive, and may be varied to suit local needs and conditions.

Demonstration and class work. Certain of these exercises are such that it will be found impossible in most high schools for the pupil to do them himself. Some are too difficult, demanding more training than the pupil has ordinarily had; others involve the use of so much apparatus that individual work is out of the question. Such exercises as the generation of oxygen or hydrogen, the use of the microscope, and the dissection of a mammal would best be demonstrated. For some of the experiments the equipment and *personnel* of the Chemistry Department could be drafted into service. Such coöperation and correlation would be of mutual benefit.

Writing up the experiments. After each demonstration the pupil should be given opportunity to describe the experiment in writing as carefully as though it had been performed by himself. The pupil may be encouraged to spend his vacant period in the laboratory making sketches of apparatus or specimens.

Home work. There are many exercises which the pupil can perform by himself or with a companion: the study of the mouth or of the eyes, the pulse, the heartbeat, reflexes, etc. These exercises may profitably be done at home.

The place of physiology on the program. Some experiments cannot be completed in a single recitation period, and if it can possibly be arranged, one of the periods of the week in this subject should be a double period, *i.e.* one running through two periods of the regular daily program. The teacher of the subject should have a vacant period immediately preceding the physiology period for preparing the laboratory work.

The use of the microscope. The study of the cell, the finer structure of the organs, the circulation of the blood, bacteria, and the like, requires a compound microscope. Each school should have at least one instrument. If the class is large, two or more instruments are highly desirable.

The ideal arrangement would be a course in Physiology taken after or parallel with a course in Biology, in which the pupil acquires microscopic technic. But this ideal rarely, if ever, exists in a high school. For this reason, and in view of the general lack of instruments, it is not deemed wise to put the preparation for microscopic work into the hands of the pupil. All microscopic study of objects is, therefore, to be prepared for by the teacher. It is suggested that the teacher prepare as many slides as are needed for a given period, and

show as many of these as possible, at the same time using as many microscopes as are available. If the teacher has six microscopes and a class of thirty pupils, six specimens should be mounted, and a label descriptive of the specimen placed beside each instrument. The pupils should pass around from one instrument to the other, making observations. While one set of pupils was thus engaged, the others would be busy making sketches and discussing the objects with the teacher.

Dissections. Dissection work can be more easily performed by the pupils than microscopic work. Any enterprising boy or girl can prepare a skeleton of a cat, or dissect the brain of a sheep or cat. Some minute dissection may be attempted in the laboratory. Most of the exercises involving dissection have, however, been given as demonstration work for the obvious gain of time by that method.

The study of bacteria. The work outlined for the study of bacterial life will prove of extreme interest to any class in Physiology. The chief difficulty to be overcome is sterilizing the dishes and the culture medium. This, however, is not insurmountable, the directions having been made as simple as possible. It is suggested that three weeks at least in a half-year course be devoted to a study of bacteria and disease.

Reading the directions. Before beginning an experiment the directions should be carefully read. The materials and apparatus needed should be prepared and assembled. The experimenter should have the object of the experiment clearly in mind from the beginning. If carried out under well-understood and carefully controlled conditions, and if the phenomena are carefully noted, correct conclusions are almost sure to follow.

Preparation for the laboratory period. It is strongly urged that every experiment, whether for demonstration by the

teacher or for class work, be performed by the teacher in advance in order that he may be certain of success before the pupils, and that everything may pass off without loss of valuable time. All the work for the following week, for example, may be prepared on a Saturday. There is no exercise in this manual which any teacher, no matter how little skilled in laboratory work, cannot perform after a trial or two.

The study of the illustrations. The illustrations should be carefully studied, as they are intended to elucidate the text and not merely to decorate the page.

Ritchie's *Human Physiology*, which this manual has been prepared to accompany, is rich in clear, instructive illustrations. This manual is the first to furnish exercises in the interpretation of illustrations of an elementary textbook. The references to the illustrations are introduced at the "psychological moment," when the impression gained by the pupil is more striking, clear, and lasting than on the first reading of the text. Ritchie's *Human Physiology* is referred to under the name *Ritchies* throughout this manual.

The pupil's notes. Much of the value of laboratory work is lost if the pupil fails to make and keep proper notes. The record of the laboratory work should be in drawings and in words, as called for in the directions at the end of each exercise. The drawings should be made on unlined drawing paper — sketched with a 3 H pencil and finished with a 6 H pencil. Notes should be written in ink. Experiments should be written up after the following outline:

a. Apparatus and material: This may include a sketch of the apparatus used.

b. Procedure: The method of setting up the apparatus and performing the experiment.

c. Observations: A record of the events (phenomena) that take place (color changes, rise in temperature, contraction of a muscle, etc.).

d. Conclusions: The "why" of the experiment, the principle learned from the experiment. The conclusion is often suggested by questions at the end of the directions.

LABORATORY MANUAL

SECTION I. ORGANIZATION OF LIVING THINGS

EXERCISE I. MATTER, INORGANIC AND ORGANIC. (CLASS WORK)

Material: A pebble; quartz or other crystals; pieces of iron, cotton, and wool; a living plant; a living animal, such as an insect.

Procedure: Discuss the properties of each object selected. After consulting a textbook of Physics, define *matter* and name some of the properties of matter. Define living and non-living matter, naming appropriate examples. Name some of the properties of matter common to both living and non-living things. Name some of the more obvious properties possessed by living things.

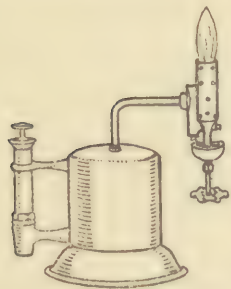


FIG. 1. A laboratory blow-torch or Bunsen burner. A good, pointed flame may be made with this. Gasoline is used as fuel. The burner can be set under a tripod upon which a vessel may be placed.

Heat each non-living object mentioned above over a flame and note which objects char (become black). Charring indicates the presence of *carbon*, a constituent of *organic* matter. All organic matter is derived from living things. Define organic; inorganic. To what is the color of black soil due? Show how coal is organic in its nature. Which parts of your desk are organic? Which are inorganic? Mention three other organic and three other inorganic objects.

Notes: Answer the questions asked in this exercise. Give examples with each definition.

EXERCISE 2. THE CELL AS THE UNIT OF STRUCTURE OF
LIVING THINGS. (DEMONSTRATION)

Experiment a. How to cut a section and mount it for microscopic study.

Apparatus and material: Microscope; slides and cover glasses; clear water and a pipette; sharp scalpel or section razor; elder pith, potato, or other object to be sectioned for study; a clean, soft rag such as a threadbare handkerchief; dissecting needles; a pair of forceps.

Procedure: Clean several slides and cover glasses. The cover glasses are easily cleaned if first dipped in alcohol.

Place a drop of water on a slide. All objects studied should be mounted in a liquid medium, usually a drop of water or a drop of staining solution. The liquid serves to hold the section in place and to make the object appear somewhat clearer to view.

To cut a section, hold a small block of potato or elder pith between the thumb and index finger of the left hand and cut the thinnest possible section with a sharp knife or a section razor held in the right hand. If the section razor is used, the blade may be made to slide over the tip of the middle finger of the left hand as the razor is pushed through the object in cutting the section. The section may be cut wedge-shaped; that is, a little thicker at one end and as thin as possible at the other. The section would then taper to almost nothing at one edge. It is at this thinnest part that the best view of the cells can be had under the microscope.

Several sections may be cut in this way and placed in the drop of water on the slide. With dissecting needles the sections are spread out so that a clear view may be had of each piece. The cover glass is now dropped over the sections.

To avoid imprisoning air bubbles, hold the cover glass by one edge with a pair of forceps, apply it to the drop of water, first at the opposite edge, and then allow it to fall upon the slide gradually. A little practice will enable one to do this skillfully. Should the drop of water prove too small to reach to the edges of the cover glass, it is not necessary to raise the cover glass in order to drive out the air. Apply a small drop of water to one edge of the cover glass. The water will enter by capillary attraction and the space under the glass will be filled. Merely applying the liquid to the edge will suffice. If too much water has been added, the surplus may be drained off by applying a small piece of absorbent paper to the edge.

The specimen is now ready for study. It is presumed that the teacher will manipulate the microscope and focus it upon the object for the pupil. The teacher should, however, show the pupil how the sections are prepared and mounted and how the microscope is manipulated.

The teacher should teach the names of the important parts of the microscope to the pupils: base, pillar, mirror, draw-tube, oculars or eyepieces, objectives, stage, diaphragm, coarse and fine adjustments. The pupil should understand how the light is reflected by the mirror and made to pass up through the drawtube and the lenses, and how it illuminates the object which is mounted on the slide and placed over the hole in the stage. The teacher should emphasize the fact that there are objectives of low and high powers. The low-power objective is in focus when about one third of an inch above the cover glass of the preparation which is being studied, whereas the high-power objective, when in focus, is very near the object and hence is in greater danger of collision with the cover glass. The pupils should be allowed to see the

same object through both low and high powers in order to form a general estimate of their relative magnifying power.

The following hints will prove helpful: (1) Do not use the high power when the low power will suffice. (2) If the high power is used, always focus with the low power first, thus finding the object and placing it in the center of the field. (3) Do not focus *down* while looking through the instrument. (4) After turning on the high power turn it down so as almost to touch the cover glass. Determine this point by placing the eye on a level with the stage of the microscope. Then with the eye at the eyepiece, focus *up* until the object comes into focus.

The teacher should have at hand one or more copies of a pamphlet on "How to Use the Microscope," published for free distribution by the company whose microscope he uses. A wall chart (also free) illustrating the instrument in section and in perspective should be owned by the school, as it will facilitate the study of the microscope.

Notes: Sketch the outline of a compound microscope and name the parts from the wall chart. Describe how a section is cut and mounted for study.

Experiment b. Pith cells of elder.

Apparatus and material: As in **a**, including pith of elder or corn.

Procedure: Make the thinnest possible free-hand section of elder or corn pith and mount it in a drop of water as described in **a**. Study with low and high powers. Note the glass-like cell walls. As these cells are dead, the protoplasmic contents are absent. Cork cells may be studied in the same way. A very thin section of potato may also be studied. Note here also the very thin glass-like cell walls and the

elliptical or oval starch grains of various sizes within the cells. The starch grains are more easily seen than the cell walls. Each cell may contain from a few to several dozen starch grains (Ritchie, Fig. 61).

The cells of plants are large and have their thick, stiff walls composed of a substance called cellulose, while animal cells have thin, flexible walls composed of albumen or they have no walls at all, as in the case of the white blood corpuscles and nerve cells. That all living things are composed of cells is known as the "cell theory." It was first announced in 1838. On account of the large size and stiff walls of plant cells, especially wood cells, the cellular structure of plants was first discovered. Soon after this discovery it was found that the bodies of animals are also composed of cells.

Notes: Sketch the cell walls of elder pith, potato, or cork.

Experiment c. An animal cell.

Apparatus and material: Microscope and prepared slide of ovary of cat or rat; egg of sea urchin or starfish or section of liver.

Procedure: Place a slide under the microscope and select one or more typical cells from the specimen. It would be well, if more than one microscope is available, to mount several typical cells. An egg cell from the ovary of a cat or rat or the egg of a starfish is an excellent example. Note the nucleus and other parts of the cell. Compare Ritchie, Fig. 1, *A* and *B*.

Note: Sketch one or more typical cells and name the parts.

Experiment d. Cells from the mouth.

Apparatus and material: Microscope; slide and cover glass; scalpel or other knife; methyl-green solution.

Procedure: Clean a scalpel and sterilize it by holding it in a flame for a moment. Scrape some cells from the inside of your own cheek. Smear the scraping on a slide and cover with a cover glass. Find large, flat cells, hardly visible at first on account of their great thinness and transparency. Note nuclei. (See Fig. 75, *The Human Body and Its Enemies*, page 121.) Add a drop of methyl-green solution, which stains the nuclei and makes them appear more distinct. (The solution will run under the cover glass as soon as the drop touches the edge of the glass; the glass need not, therefore, be raised to add the solution.)

Notes: Sketch several flat cells from the mouth as they appear under the microscope.

Experiment e. Paramecium, a one-celled animal.

Apparatus and material: Microscope; slide and cover glass; 2 % acetic acid solution; 8 % gelatin solution (not absolutely necessary); culture of Paramecium.

Procedure: Make a hay infusion or hay "tea" by steeping a handful of chopped hay in a pan of warm water. Set it aside in a warm place, partly covered with a glass plate to prevent too rapid evaporation. In a few days decay will set in, due to the action of the rapidly multiplying bacteria. Later, Paramecia will abound in countless numbers, feeding upon the bacteria. The white scum on the surface of the culture will be especially rich in the animalcules.

Mount a drop of the infusion on a slide and note the Protozoa (see Ritchie, pages 5 and 285) as well as the bacteria. The former will be seen as comparatively large, one-celled animals swimming actively about in the liquid. The bacteria are very tiny rod-shaped objects swimming about with a zig-zag or vibrating movement.

If mounted in a drop of gelatine solution (about 8 %) which is just liquid at room temperature, the swimming of the *Paramecia* will be retarded and their study greatly facilitated. Note the action of the cilia (Ritchie, Fig. 3). After the living animals have been studied, kill them by adding to the slide a drop of 2 % acetic acid. Note that the cilia are thrown out as the *Paramecia* die from the effects of the acid.

Notes: Sketch several *Paramecia* with their cilia.

EXERCISE 3. REPRODUCTION OF CELLS. (DEMONSTRATION)

Experiment a. *Paramecium*.

Apparatus and material: Same as Exercise 2, e.

Procedure: In the *Paramecium* culture described in the preceding exercise (2, e) note dividing individuals as shown in Ritchie, Fig. 3; with a little perseverance a number of these will be found. When found, kill with 2 % acetic acid, otherwise the individual animalcule to be shown will swim out of the field of vision.

Notes: Sketch a dividing *Paramecium*.

Experiment b. Yeast.

Apparatus and material: Microscope; slides and cover glasses; yeast cake; 10 % molasses solution; the apparatus shown in Fig. 2.

Procedure: Make a yeast culture as follows: Fill a wide-mouthed bottle with 10 % molasses solution (10 parts of molasses in 90 parts of water) and add to this one fourth of a yeast cake. Place a little molasses solution in a dish and invert the bottle in the dish (Fig. 2), taking care that the bottle remains full. To accomplish this, cover the mouth of the bottle with cardboard, hold the cardboard in place while

inverting the bottle, and remove the cardboard after the inversion has been accomplished. The mouth of the bottle should be raised a little above the bottom of the dish by a couple of nails or matches. Set the culture aside in a warm place. At the end of 24 hours study the yeast cells in a drop of liquid taken from the surface or from the bottom of the liquid in the dish. Note budding yeast cells as shown in Ritchie, Fig. 112. The yeast cells multiply by growing "buds," each of which becomes a new yeast plant.

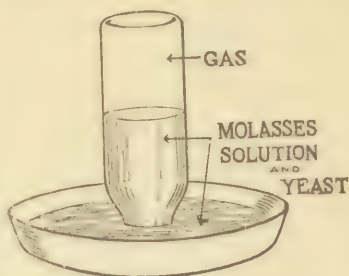


FIG. 2. The fermentation of molasses by yeast plants. See Exercise 3, b.

Notes: Sketch several "budding" yeast plants.

Experiment c. Cartilage cells.

Apparatus and material: Microscope and prepared section of cartilage tissue.

Procedure: Study prepared slide of cartilage tissue. Note the cells within pockets or lacunæ of the tissue. Note that some lacunæ contain more than one cell; these cells are dividing or multiplying. (See Ritchie, Fig. 26.)

Notes: Sketch several dividing cartilage cells.

Experiment d. Sea-urchin eggs.

Apparatus and material: Microscope and prepared slide of dividing sea-urchin or starfish eggs.

Procedure: Study prepared slide of dividing sea-urchin eggs, showing 2-, 4-, 8-, 16-, 32- and more cell stages. Every animal or plant begins as a one-celled form; namely, from an egg produced by the mother plant or animal. This

cell multiplies, in higher forms, until the complex body of the plant or animal results. (See Ritchie, page 6.)

Notes: Sketch eggs in different stages of division.

EXERCISE 4. ARRANGEMENT OF CELLS INTO TISSUES.
(DEMONSTRATION)

Experiment a. Cartilage tissue.

Apparatus and material: Microscope; prepared slide of cartilage tissue (as in Exercise 3, c); also, if desired, fresh cartilage from the end of a bone; sectioning knife or razor; slides and cover glasses.

Procedure: Study the preparation of cartilage tissue. Note that the tissue consists of cells and the ground substance between the cells. (See Ritchie, Fig. 26, *a* and *b*.)

It is instructive also to study a fresh specimen of cartilage tissue. Cut a free-hand section of cartilage from the end of a long bone, *e.g.* of a "drumstick." The femur of a frog soaked in alcohol or formaldehyde will do very well. Study the section mounted in a drop of water or dilute alcohol; compare with the stained preparation. (Study Ritchie, page 59, footnote.)

Notes: Make a drawing of cartilage tissue.

Experiment b. Connective tissue.

Apparatus and material: Microscope; slides and cover glasses; dissecting instruments; Ringer's solution; methyl-green solution; dead mouse; piece of ligament from back of neck of ox.

Procedure: How to kill an animal: Under no circumstances should an animal be experimented upon alive or tortured in any way. When the experimenter is ready, the animal

should be killed by chloroforming it. Select an air-tight box or a glass or earthenware jar suitable to the size of the animal. A five-gallon jar is a good size for a chloroforming jar. Drop a rag or tuft of cotton saturated with chloroform into the bottom of the jar. Then place the animal in the jar and cover it. The animal will soon be dead.

Cut off and skin the tail of the mouse. Long white tendons are now visible running along the tail. Pull off a tendon with a pair of forceps and place it in a drop of water on a slide. With dissecting needles tease out the tendon, *i.e.* tear it apart into fine shreds. Cover the preparation with a cover glass and study the tissue under the microscope. Note the fibers. Tease out another bit of tendon in methyl-green. Are cells now visible in such a stained preparation? (See Ritchie, page 8.) The tendon just studied is white connective tissue and is inelastic, *i.e.* it will not stretch, as may be demonstrated with a piece of the loose tendons from the leg of an ox or a pig. Elastic (yellow) connective tissue may be taken from the large ligament found in the neck of cattle. This ligament is called the *ligamentum nuchæ*. It serves to hold up the head. Being elastic, it stretches when the animal wishes to lower the head, as when grazing. Obtain a piece of this ligament from a butcher. Demonstrate its elastic qualities. If desired, a bit of this tissue may be treated and studied as described above for the preparation of a tendon from the tail of a mouse. The connective tissue layer under the skin and the connective tissue framework of most of the tissues and organs contains an admixture of yellow elastic fibers.

Notes: Sketch connective tissue and show how the footnote, Ritchie, page 59, applies to this tissue.

Experiment c. Epithelial tissue.

Apparatus and material: Microscope; prepared slides of skin, of trachea or esophagus and of stomach or intestine.

Procedure: In epithelial tissue the cells are arranged like the bricks of a pavement. In some organs the epithelial tissue serves to cover surfaces; as, *e.g.* in the outer skin (Ritchie, Figs. 5, 93, 94, 96, 113, 116). In other organs the tissue lines cavities (Figs. 6, 47, 49, 51, 55, 76). These figures should be studied by the class before the slides are studied. The teacher will then focus the microscope on the epidermis of the skin, on the lining of the trachea (or the esophagus), and on the lining of the stomach (or the intestine). Note that epithelial tissue of the skin is many cells thick and that of the stomach and intestine only one cell thick.

Notes: Sketch a portion of each organ studied, showing the epithelial tissue.

Experiment d. Muscle tissue.

Apparatus and material: Microscope; slides and cover glasses; dissecting needles; Ringer's solution; small piece of muscle from breast of cooked chicken; also portion of muscular wall of chicken's gizzard.

Procedure: Pull out a very small bundle of muscle from the breast of the chicken and tease out the specimen into the finest possible shreds. Study it under the high power of the microscope. Can you see the muscle fiber with its cross stripes as represented in Ritchie, Fig. 35, *B*?

Treat the muscle from the gizzard in the same manner. The muscle fibers here do not exhibit cross stripes; they are smooth (unstriped) or involuntary muscle fibers. Can you find muscle cells as shown at the top of Ritchie, Fig. 5? Explain how the cells fit together to make a tissue.

Notes: Sketch several muscle fibers of each kind, as seen. Tell where each kind of fiber is taken from and describe how it was prepared for study.

Experiment e. Nerve tissue.

Apparatus and material: Same as in preceding experiment, substituting a nerve of some animal for a muscle.

Procedure: A nerve may be found as a shining white cord, not so glistening or so tough as a tendon, in the flesh of any animal. Tease out a portion of a nerve on a slide and study it. Note the nerve fibers. No cells will be seen, for a nerve consists of fibers only, the cells being situated in central stations called ganglia or in the brain or spinal chord. (See Ritchie, Fig. 15.) The nerve cell could be studied in a prepared section of one of these organs.

Notes: Sketch a nerve which has been torn apart to show the fibers.

EXERCISE 5. ARRANGEMENT OF TISSUES INTO ORGANS. (CLASS WORK)

Experiment a. A muscle.

Material: A small muscle, such as a muscle of a toad or a frog; dissecting needles.

Procedure: Dissect a muscle and note as many kinds of tissue as you can. (Cf. Ritchie, Figs. 35 and 36.)

Notes: Describe this experiment and make a list of the tissues found.

Experiment b. Other organs. (Home work.)

Material: Ritchie, Figures 49, 91, and 93-96.

Notes: From a study of the appropriate figures in Ritchie make a list of tissues that enter into the formation of the stomach, the kidney, and the skin.

EXERCISE 6. PLAN OF THE BODY. ARRANGEMENT OF ORGANS.
(CLASS WORK)

Experiment a. A simple plan : Hydra.

Apparatus and material: Microscope, and prepared cross section of hydra.

Procedure: Study a cross section of a hydra under the low power of the microscope. Note the ring of cells. This is the wall of the animal, which consists merely of a hollow sack, attached at one end and open at the other.

For further studies of the Hydra consult a textbook of Zoölogy.

Notes: Sketch a cross section of the Hydra.

Experiment b. The double-tube plan : the earthworm.

Apparatus and material: Microscope ; hand lens ; and prepared cross section of an earthworm.

Procedure: Study the cross section of an earthworm under a hand lens and under the microscope. Note the body wall (largely muscular) on the outside and the intestine on the inside. The latter is suspended from the wall above by a mesentery. The space between the body wall and the intestine is the body cavity. The plan of structure of the earthworm is thus that of a tube within a tube.

Study Ritchie, Fig. 9, and note how the human body conforms to the general "double-tube" plan of structure.

Experiment c. Exo-skeleton and endo-skeleton.

Apparatus and material: Insects, such as grasshoppers, crickets, or cockroaches ; a frog or toad ; dissecting instruments ; dissecting boards or pans ; killing jar or box ; chloroform. What insect is used depends upon the season of the

year. In spring and fall grasshoppers are available; in winter cockroaches may be caught in grocery stores, bakery shops, and other places, especially at night. Toads may be found at night in gardens or on lawns, and frogs may be captured about springs or ponds at certain seasons.

Procedure: The toad or the frog may be skinned thus: slit the skin lengthwise from the jaw back. Then slit it across the middle of the body. The skin may now be pulled off like a glove. Cut off a leg of an insect and a leg of a frog. Study the cut ends. Note that the insect has the skeleton on the outside and the muscles on the inside. Compare the condition in the frog with that in the insect. Feel your own arm and note the relation of bone to muscle. (See Ritchie, Fig. 39.)

Study Ritchie, Fig. 9. Note that the intestines are in the ventral cavity, and that the spinal cord and brain (central nervous system) are on the dorsal side. (See Ritchie, page 16, footnote.)

Lay the frog on its back and open the body cavity by slitting open the ventral wall of the abdomen. Note the intestine. Find the backbone. Turn the frog over and cut open the backbone, exposing the spinal cord. (Do not injure the spinal cord, for the same specimen should be used again.) It is thus seen that the frog, as well as the human being, has the central nervous system dorsal to the intestine.

Lay the cockroach or grasshopper on its ventral surface in a dissecting tray. This is sometimes best done with enough water in the tray to cover the insect, worm, etc. The insect may be fastened to the beeswax by pins. With a pair of scissors cut off the dorsal wall, thus exposing the intestine and other organs in the body cavity. Push them aside and

note the "nerve chain" on the ventral surface. The nerve chain is seen to consist of nerve fibers and a series of ganglia, or knots of nerve tissue. It is thus found that the insect has the nervous system ventral to the intestine.

Notes: Sketch a longitudinal section of a frog after the plan of Ritchie, Fig. 9, and beside it place a sketch of a similar section of the insect. Let each drawing show body wall, skeleton, nerve chain, and intestine.

EXERCISE 7. THE CLASSIFICATION OF VERTEBRATES. (HOME WORK)

Experiment a. The classes of vertebrates.

Reduce the diagram, Ritchie, Fig. 11, to outline form, adding to the outline the characteristics of the five great classes of vertebrates according to footnote, page 18. To what class does man belong? Why?

Experiment b. Comparison of man with other mammals.

Material: Illustrations in Ritchie; a textbook in Zoölogy; skeletons or parts of skeletons of various animals brought into the laboratory by the pupils.

Notes: Write out a comparison of man and other mammals as to : (1) The position of the axis of the body. (2) The various means of locomotion among mammals and the resulting differences in fore and hind limbs. (See Ritchie, Fig. 33.) Why are the fore and hind limbs much alike in the horse but different in man, the bat, the whale, and the kangaroo. (3) The elimination of the tail as a functional organ. (4) The increase of the hemispheres of the brain. (5) The change of facial angle. (Cf. Ritchie, Figs. 17 and 32.) The study of the classification of mammals may be pursued further by reference to textbooks on Zoölogy.

EXERCISE 8. GENERAL VIEW OF THE NERVOUS SYSTEM.

(DEMONSTRATION)

(To illustrate Ritchie, Chapter III)

Experiment a. The central nervous system.

Apparatus and material: The toad used in Exercise 6, c, above; dissecting instruments.

Procedure: Continue the dissection of the nervous system as begun in Exercise 6, c, by cutting away enough of the vertebræ on the dorsal side of the animal to show the entire spinal cord. Remove also the roof of the skull, exposing the brain. A strong pair of fine-pointed scissors will be found useful for removing the bone, piece by piece. The dissection, if well done, should be preserved in 5% formaldehyde and kept from year to year. The covering of the vessel may be sealed with paraffin to prevent evaporation of the formalin.

Notes: Sketch the central nervous system (brain and spinal cord) of the frog.

Experiment b. The sympathetic nervous system.

Apparatus and material: The toad used in the preceding experiment; dissecting instruments.

Procedure: Remove all the viscera of the animal. Lay it on its back. The dorsal wall of the ventral cavity is now in view. A careful search will disclose a chain of ganglia connected by nerves lying close against the dorsal wall of each side of the ridge which marks the spinal column. These two nerve chains with their fibers belong to the sympathetic nervous system (Ritchie, Fig. 105).

Notes: Sketch the sympathetic nerve chains of the frog.

Experiment c. Reflex action.

Apparatus and material: Frog or toad, recently killed; 10% acetic acid.

Procedure: Stretch the hind leg of the frog and let go; the leg is drawn up. Touch the hind foot with a drop of 10% acetic acid; the foot is withdrawn. Touch the chest with a drop of acid. What is the result?

Notes: Describe several experiments illustrating reflex action.

Experiment d. Function of a nerve.

Apparatus and material: The frog or toad used in the preceding experiment; a glass rod; the apparatus shown in Fig. 6.

Procedure: Lay bare the sciatic nerve as described in Exercise 22, a. Stimulate the nerve (1) by pinching it at a point as far from the foot as possible. What is the result? Stimulate the nerve (2) by touching it with a hot iron. Stimulate the nerve (3) by applying an electric current from a dry cell. Do you observe any change in the nerve on stimulation? What is the function of a nerve? Of what is a nerve composed? (Review Exercise 4, e, and see Ritchie, Fig. 15.) Name the three kinds of stimulation employed in this experiment to stimulate the nerve.

Notes: Answer the questions asked in this exercise. Describe how the experiments were performed, drawing figures where necessary.

SECTION II. THE ORGANS OF LOCOMOTION

EXERCISE 9. THE SKELETON. (CLASS WORK)

Experiment a. The human skeleton.

A human skeleton should be studied in connection with Ritchie, Chapter IV. If the school does not possess a specimen, it may be possible to borrow one from a physician of the community. Study advanced textbooks for suggestions. It will be well for the teacher to lecture to the class on the parts of the skeleton and their uses and peculiarities, illustrating each point by reference to the skeleton. A definite knowledge of the most important things to be noted in the skeleton may thus be acquired in a few periods.

Experiment b. Skeleton of a cat.

It is possible to illustrate many important features by using the skeleton of a mammal, such as the cat. To prepare a skeleton: Kill the cat by chloroforming it, skin it, remove the viscera without injuring the chest bones, and cut off all the flesh possible with a scalpel and scissors. Then boil the animal for a short while in the following "liquid soap" mixture: water 2000 c.c.; ammonia, 150 c.c.; saltpeter, 12 g.; laundry soap, 75 g. Boil the skeleton until the muscles have softened but the ligaments still hold together. If it is desired to disarticulate the skeleton, the bones must be boiled longer. It may be well to disarticulate the head and limbs before boiling. To prevent the vertebral column from coming to pieces, the vertebræ may be "strung" on a strong piece of twine or on a wire which is run through the neural canal. With patience any pupil may make an excellent preparation of a skeleton. The pupils should be encouraged to bring the skeletons of various small animals. The school may thus easily acquire specimens of all the vertebrate limbs shown in Ritchie, Fig. 33.

EXERCISE 10. OBSERVATIONS ON THE SKELETON. (CLASS
WORK)

Experiment a. Classification of the bones.

Material: A skeleton.

Procedure: On the human skeleton study the bones named in Ritchie, Chapter IV, and especially in Fig. 16. If only the skeleton of the cat is available, make out all the corresponding bones of the cat. Classify every bone (1) according to shape and (2) according to use.

Notes: Make a list of classes of bones (long, short, flat, etc., or for protection, motion, etc.), and under each class a list of bones coming under that class. Use the names of bones given in Ritchie, Figs. 16 and 17.

Experiment b. Comparison of human limbs with limbs of other vertebrates.

Material: Bones of animals; disinfectant, such as formaldehyde or corrosive sublimate.

The ingenuity and enterprise of the pupils can be relied upon to bring in or prepare, according to Exercise 9, b, material for this study. If bones of dead animals are brought in from the fields, they should be thoroughly scrubbed with 5% formaldehyde solution or a saturated solution of corrosive sublimate, or disinfected by being boiled in water, before being handled by the class. Greasy bones may be cleansed by boiling in strong soapy water.

Procedure: As many comparisons as possible should be drawn between human limbs and those of the animals represented in the collection. If such material is not at hand, the living bird (chicken, etc.), horse, cow, frog, mole, or bat may be compared with the human body.

Notes: Write out as many comparisons between the limbs of various animals and those of man as time will permit.

Experiment c. Comparison of the upper and the lower limbs of man (Home work.)

Material: Observations on one's own body; a skeleton would prove helpful.

Procedure: Point out the differences in structure and in use of the arms and legs. Show how the legs are adapted to carry the weight and note that the arms have freedom of motion rather than strength. Compare the shoulder joint with the hip joint; the elbow with the knee; the ankle with the wrist; the upper arm with the thigh; the forearm with the shank; the foot with the hand.

Notes: Write up the observations made.

Experiment d. The articulation of the vertebræ with one another.

Material: Several successive vertebræ.

Procedure: Select several successive vertebræ, as in Ritchie, Fig. 21, and make out the manner of interlocking of vertebræ. What are the functions of the various processes of the vertebræ? (Study Ritchie, Figs. 21, 41, and 42.)

Notes: Make a drawing similar to Ritchie, Fig. 21, but draw from the objects, do not copy the drawing.

Experiment e. The rotation of the hand.

Material: Skeleton.

Procedure: Make out how it is possible for us to rotate the hand, *i.e.* to turn it palm up or palm down. Note rotation of radius at its pivot joint at the elbow. (See Ritchie, Fig. 33, B.)

Notes: Describe the observations made in this exercise.

EXERCISE II. THE STRUCTURE OF THE BONES. (CLASS WORK)

Experiment a. A long bone.

Material: A femur or humerus of a dog or pig or the "drumstick" of a chicken; a fine hacksaw.

Procedure: Saw the bone lengthwise as shown in Ritchie, Fig. 25. Saw also a cross section of the shaft. Perform the experiments described in Ritchie, page 41.

Notes: Make drawings of the longitudinal and the cross section of a long bone. Write up the experiments to show why the shaft is hollow.

Experiment b. A flat or irregular bone.

Material: A rib or a vertebra.

Procedure: Compare a cross section of the shaft of a long bone with a similar section of a rib or a vertebra. Compare the red and the white marrow.

Notes: Sketch a cross section of a rib.

EXERCISE 12. STRUCTURE OF BONE TISSUE. (CLASS WORK)

Apparatus and material: Microscope; prepared slide of bone tissue. If it is desired to prepare the sections in the laboratory, the following things are needed: long bone of dog or cat; fine hacksaw, whetstone, and water.

Procedure: Study the sections of bone tissue with the microscope. Use as a guide, Ritchie Fig. 23. Fig. 23, *A*, shows the canals both in cross section and longitudinal section. Find the canals and the lacunæ surrounding them. The lacunæ are the homes of the bone cells. Turn on the high power and compare the view with, Fig. 23, *B*.

To prepare sections of bone, proceed as follows: Saw the

thinnest possible cross section from the end of the bone and also a similar longitudinal section. These pieces are still far too thick for study. Grind them down on a whetstone. Place a section on the stone, add a little water, and then rub with the finger until the section is very thin, when it is ready for study.

Notes: Sketch a cross section of bone tissue as seen under the microscope.

EXERCISE 13. MATERIALS IN BONES. (CLASS WORK)

Material: A long bone, *e.g.* a drumstick; 5-10 % hydrochloric acid.

Procedure: Perform the experiments as directed in Ritchie, page 39.

Notes: Explain the results obtained.

EXERCISE 14. USES OF OTHER SKELETAL TISSUE. (CLASS WORK)

Experiment a. Connective tissues.

Material: The hip joint of a frog or toad and several long muscles with their tendons. (These specimens may be preserved in 5 % formaldehyde from year to year.)

Procedure: Study the ligaments by which the bones are held together at the hip joint. Review Exercise 5, a. Study the tendons of the muscles and follow them as far as possible into the body of the muscle. An examination of a tendon with the point of the muscle joining it is instructive.

Notes: State the chief functions of connective tissue.

Experiment b. Cartilage.

Material: Human skeleton or separate bones of cat, frog, chicken, or other animal; hip joint used in preceding experiment.

Procedure: Illustrate the uses of cartilage by pointing out (1) the smooth, tough capping for long bones (Ritchie, Fig. 25); (2) the lining of articular facets or sockets (Ritchie, Fig. 27); (3) the connection of ribs and sternum (Ritchie, Fig. 19); (4) the packing between vertebræ (Ritchie, Fig. 21). Also feel your own nose and ear, which are made stiff (but flexible) by means of cartilage.

Notes: State the uses of cartilage in the body.

EXERCISE 15. KINDS OF JOINTS. (CLASS WORK)

Material: A skeleton.

Procedure: *a.* Sutures of the skull. A skull of a cat or other animal will do very well to illustrate this class of joint. Note how firmly the bones are knit together. (Cf. Ritchie, Fig. 17.)

b. Gliding joint. Study the articulation of two successive vertebræ (Ritchie, Fig. 21). How much motion is possible between vertebræ? Study also the wrist and ankle joints.

c. Hinge joint. Study the knee joint; also the articulation of the ulna and the humerus at the elbow. The elbow has two distinct joints.

d. Ball-and-socket joint. The hip and the shoulder are examples of this class. The former may be studied in detail (see below).

e. Pivot joint. Review Exercise 10, *e* above. If the human skeleton is not available, demonstrate the rotation of the radius in your own arm. Flex the right arm at the elbow, holding the forearm horizontal. Press upon the radius near the elbow with the fingers and, as you rotate the hand alternately palm up and palm down, observe that the radius rotates at the elbow and that the ulna remains stationary.

Notes: Name the classes of joints, give examples of each, and state the motion each allows to the articulating bones.

EXERCISE 16. STRUCTURE OF A BALL-AND-SOCKET JOINT.
(CLASS WORK)

Material: A hip joint of a pig from the butcher.

Procedure: Study Ritchie, Fig. 27. The upper larger drawing shows the "capsular" ligament. Cut this partly in two in the specimen, so as to expose the inner structure of the joint. Note the smooth, moist surfaces. What parts do cartilage and connective tissue play in a joint? Find the round ligament (compare lower drawing, Fig. 27).

Notes: Describe a joint either in words or by drawings.

EXERCISE 17. PROTECTION OF THE BRAIN. (HOME WORK)

Material: The sticks shown in Ritchie, Figs. 28, 30, and 31; a human skeleton.

Procedure: Perform the experiments as illustrated by Ritchie, Figs. 28-31. Compare Fig. 31 with the curvatures of the spinal column. Compare Ritchie, Figs. 18 and 31. Study also Ritchie's *Primer of Physiology*, pages 33-37.

Notes: Write several paragraphs showing how tight, high-heeled shoes injure the arch of the foot.

EXERCISE 18. FRACTURES AND SPRAINS. (CLASS WORK)

Material: Pillow; wooden sticks about two feet long; pieces of rope; X-ray pictures of fractures.

Procedure: After having studied page 55 in Ritchie, the subject may be pursued further in the Red Cross abridged textbook on First Aid to the Injured. The pillow splint should be demonstrated to the class, one of the boys acting as subject. (See Fig. 239, *The Human Body and its Enemies*.) X-ray pictures of fractures, borrowed from a physician or taken from

a magazine, may be shown to the class. (When once acquired, these pictures should be saved from year to year.)

Notes: Describe a pillow splint as applied in the demonstration.

EXERCISE 19. LEVERS OF THE BODY. (HOME WORK)

Apparatus: A ruler for a lever; any other objects for fulcrum and weight: a pair of scissors, a nutcracker, a pair of sheep shears, one's own body.

Suggestions: Since the larger movements of the body are brought about by the action of muscles in connection with

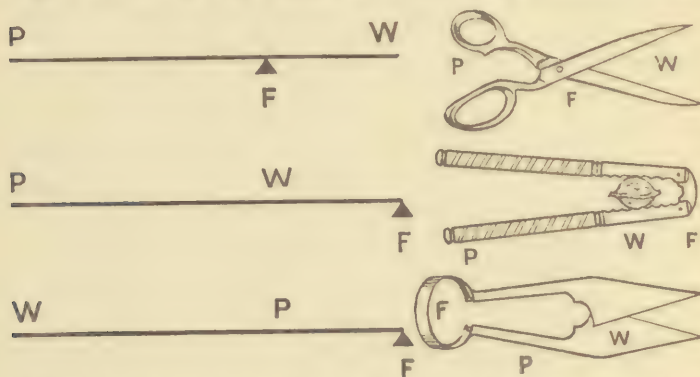


FIG. 3. The arrangement of fulcrum, weight, and power in the three classes of levers. To the right, common examples of the use of levers in mechanical appliances.

bones, the latter are said to serve as levers. Examples of the three classes of levers recognized in mechanics are found in the human body. If time permits, the teacher may construct an interesting series of exercises by having the class find examples in the body of each class of lever. Figure 3 and the following suggestions may be helpful:

A lever of the first class has the fulcrum (F) between the power (P) and the weight (W). Example: pair of scissors.

Example from body: striking table with fist. Consult Ritchie, Fig. 39. In striking the table, the power is applied by the triceps muscle to the end of the ulna of the forearm, the elbow joint is the fulcrum, and the weight is the hand.

A lever of the second class has W between P and F . Examples: nutcracker, wheelbarrow. Example from body: rising on toes. Here the weight is the body, the fulcrum is at the toes, and the power is applied to the heel bone by the muscles at the calf of the leg. (Cf. Ritchie, Fig. 29.)

A lever of the third class has P between F and W . Example: sheep shears. Example from body: holding weight in the hand.

Procedure: Place the ruler in position to represent a lever of each of the three classes described above. Study the levers involved in the scissors, nutcracker, and sheep shears. Study the levers of the body as indicated above. Determine also the class of lever involved in the following movements: nodding, bowing, curtsying, standing on heels, tapping floor with toes, pressing index finger and thumb together, kicking, raising leg from lying position.

Notes: Sketch Ritchie, Fig. 29, A , and indicate the P , F , and W in the drawing. Appropriate sketches may be made of the parts involved in the movements of the limbs stated in the procedure above. Indicate the P , F , and W in each case.

EXERCISE 20. A STUDY OF TENDONS. (CLASS WORK)

Experiment a. The long tendons ("leaders") of the foot and the hand.

Material: Foot of a bird; the human hand.

Procedure: One of the pupils might dissect out the foot and drumstick of a bird, following several tendons from their

muscles in the shank to their attachment in the foot. Such a specimen should be preserved for future use.

Hold your hand out before you, palm down; move the fingers in every way possible, noting the action of the tendons as seen under the skin. Compare Ritchie, Fig. 37.

Notes: Sketch several tendons in the foot of some animal.

Experiment b. Illustrating the action of a tendon.

Material: A piece of string; one's own hand.

Procedure: Perform the experiment described in Ritchie, page 65.

Notes: Answer the questions asked in directions, Ritchie, page 65.

EXERCISE 21. STRUCTURE OF A MUSCLE. (CLASS WORK)

Material: A long tapering muscle of a cat or a frog, soaked for several days in 1 % formaldehyde or in 30 % alcohol or softened by boiling in water.

Procedure: Cut the muscle as represented in Ritchie, Fig. 35, *A*. Note the bundles as shown. With dissecting needles tease the muscle apart, beginning at the tendon. The object of this exercise is to show that the "connective tissue skeleton" of the muscle (Ritchie, page 63) is continuous with the tendons at the ends, as shown in Ritchie, Fig. 36.

Notes: Discuss the reason why a round steak cut near the end of a muscle is tougher than that cut from the middle of a muscle.

EXERCISE 22. THE WORK OF MUSCLES. (DEMONSTRATION)

Experiment a. How to make a muscle-nerve preparation.

Materials: Living frog or toad; chloroform; dissecting set, including a strong pair of scissors; a board about 6 by 10 inches; a small piece of sheet rubber; normal salt solution,

three tacks, hammer, string, a pin bent into a hook, a weight (a tenpenny nail will do for a weight).

Procedure: Kill the frog or toad by chloroforming it (see Exercise 4, b). Cut off the head. Slit open the ventral cavity and remove the entrails, saving the heart for Exercise 23. (This experiment should be begun at once, as the heart will continue to beat for some time.) Remove the skin of the frog. To do this, simply make a circular incision through the skin around the body and then pull the legs out of the skin as one would pull the fingers out of a tight-fitting glove. Cut off the upper two thirds of the trunk. There now remain only the pelvis and the hind legs. Split the pelvis in two lengthwise. Each of the two halves with its attached leg will furnish a preparation. While experimenting with one, the other should be covered with cotton soaked in normal salt solution until the experimenter is ready to use it.

In the thigh of the frog's leg find the sciatic nerve by the aid of Figure 4. The nerve will be found together with the femoral artery and vein under the narrow, band-like biceps muscle (Fig. 4, *B*) or in the furrow (*F*). Push aside the muscle or cut it away, exposing the nerve, a white strand accompanying the blood vessels mentioned. Free the nerve

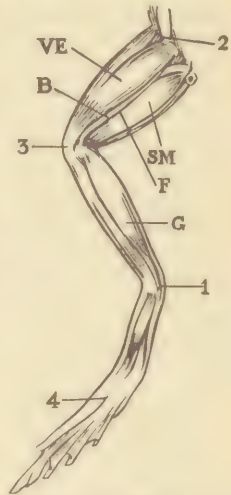


FIG. 4. The right leg of a frog, with the skin removed. *VE* and *SM*, large muscles of the thigh; *B*, biceps muscle; *F*, furrow in which the femoral artery, the femoral vein, and the sciatic nerve are found (usually under the biceps muscle); *G*, the gastrocnemius muscle, used in the experiments; *1*, its tendon (tendon of Achilles); *3*, the patellar ligament; tacks are driven through points 2, 3, and 4 in mounting the leg on a frog board. (See also Fig. 5.)

with a pencil point. Insulate the nerve by slipping under it a small piece of sheet rubber.

The preparation is now ready for stimulation, but it may first be mounted on a board, as shown in Fig. 5. Drive tacks through the points shown (*i.e.* at 2, 3, and 4, Fig. 4), es-

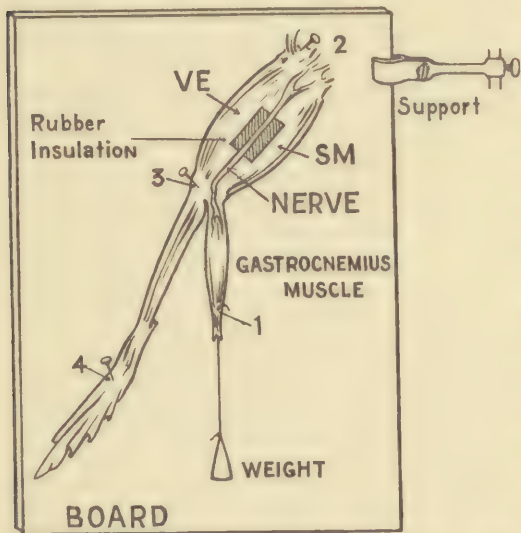


FIG. 5. Method of mounting a frog's leg on a board. Numbers and letters are the same as in Fig. 4. The biceps muscle has been removed and the sciatic nerve exposed.

pecially through the tendon at the knee. Cut the tendon of the gastrocnemius muscle (Fig. 4, *G*) loose at the lower end (Fig. 4, *I*), leaving as much of the large tendon attached to the muscle as possible. By means of a hooked pin and a string a weight may be attached to the tendon. The preparation may now be mounted

vertically, as shown in the illustration (Fig. 5). When the nerve is stimulated, the muscle will contract and raise the weight.

Caution: The nerve should be kept constantly moist with normal salt solution.

Notes: Sketch the leg of a frog, showing the gastrocnemius muscle and the sciatic nerve.

Experiment b. How to stimulate the nerve.

Apparatus and material: The muscle-nerve preparation just described; the electric apparatus shown in Fig. 6. (See legend under figure.)

Procedure: It is readily seen from a study of Fig. 6 that if the connection is made between the tips of the wires of the electrode, the circuit is completed, and the electric current



FIG. 6. Electrical apparatus for stimulating the nerve. The wires from the electrical dry cell are passed through glass tubes and allowed to protrude for about $\frac{1}{4}$ inch at the other end. The wires may be sealed in place with sealing wax and the glass tubes tied together for a handle. No current passes until the ends of the wires are connected; as for example, when the ends of the wires are touched to the nerve.

will run through the wires. On touching the nerve with the tips of the wires, therefore, the current will enter the nerve and stimulate it. A muscular contraction should follow the stimulation.

If the experiment is not successful at first, bring the wire tips closer together. If still unsuccessful, the current is, perhaps, not strong enough to pass through the nerve; in which case, use two dry cells, connecting the carbon of one with the zinc of the other.

Review in this connection Exercise 8, d.

Notes: State some of the functions of nerves. Describe an experiment to show that stimulation of the nerve causes contraction of the muscle to which it passes.

Experiment c. Tetanus.

Apparatus and material: The same as in the preceding experiment.

Procedure: Touch the nerve frequently in as rapid succession as possible, or arrange a small vessel of mercury in the circuit, and then make and break the circuit by quickly dipping the end of one of the wires into the mercury and withdrawing it. A continuous contraction of the muscle results if the stimuli are in sufficiently rapid succession. This continued contraction is called tetanus. The muscle does not have time to relax before the next impulse to contract comes on.

Notes: Look up the word "tetanus" in the dictionary. The word is also used as the name of the disease, tetanus or lockjaw (Ritchie, page 313). State the reason why the name of the disease should be taken from the name of the phenomenon of tetanus in muscles.

Experiment d. Fatigue.

Apparatus and material: Same as in b above.

Procedure: Stimulate the muscle once each second until the muscle becomes exhausted. This phenomenon of exhaustion is called fatigue. Cut the muscle across and test it for acidity with litmus paper.

Notes: Describe an experiment of your own, showing how a muscle of your arm may become fatigued. How does it recover from fatigue?

EXERCISE 23. RHYTHMIC CONTRACTION. (DEMONSTRATION)

Apparatus and material: Heart of a frog; small, shallow vessel containing Ringer's solution at ordinary temperature; a quantity of ice-cold Ringer's solution and a quantity of hot Ringer's solution.

Procedure: Place the frog heart in Ringer's solution at

ordinary temperature. Note the beating of the heart. Slowly add ice-cold solution to the liquid containing the heart. Then slowly add hot solution so as gradually to warm the liquid containing the heart. Note the effect of temperature on the rate of the heartbeat.

Notes: Describe the effect of temperature on the contraction of the heart. Does temperature have this effect on the voluntary muscles? How do you know this?

EXERCISE 24. MODEL OF ARM. (DEMONSTRATION)

Apparatus and material: The apparatus shown in Fig. 7, including two muscle-nerve preparations of a frog; the electrical apparatus shown in Fig. 6.

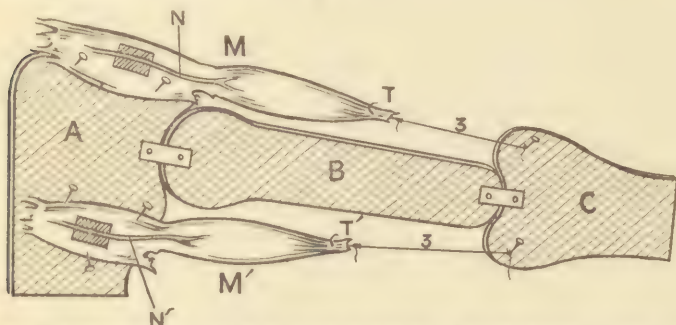


FIG. 7. Model of arm, made of three pieces of thin board and two muscle-nerve preparations.

Procedure: The purpose of this experiment is to show the antagonistic action of muscles. Construct the model shown in Fig. 7, which is one half natural size. A, B, and C are thin pieces of wood (*e.g.* sides of a cigar box) hinged together as shown. M and M' are muscle-nerve preparations prepared as directed above (Exercise 22, a), but the shank of the leg is cut

off below the knee. One end of each muscle-nerve preparation is tacked to *A*. The free tendon *T* of the muscle is tacked to *C* directly, or, if the muscle is too short, the tendon is tied to *C* by means of a string (3). The nerves *N* and *N'* passing to *M* and *M'* are insulated. The muscles are made to contract by stimulating the nerve with an electric shock, as in Exercise 22. Stimulate *N* and *N'* alternately. Compare the result with the action of the biceps and the triceps of the human arm. One of the muscle-nerve preparations would represent the biceps and the other the triceps (Ritchie, Fig. 39).

Notes : Make a sketch of the apparatus used to illustrate the antagonistic action of muscles.

SECTION III. FOODS AND DIGESTION

(To illustrate Ritchie, Chapter VII)

EXERCISE 25. MATTER AND ENERGY. PHYSICAL CHANGES. (CLASS WORK)

Experiment a. Water as solid, liquid, and gas.

Apparatus and material: Evaporating dish or shallow tin pan; a piece of ice; thermometer; Bunsen burner.

Procedure: Place a piece of ice in a shallow dish. Warm it and watch the ice liquefy (melt). Note the temperature throughout the experiment, stirring the water so that the average temperature of the liquid is recorded. How long does the liquid remain near freezing? Heat the water to boiling. Can you heat it higher than 212° Fahrenheit ($= 100^{\circ}$ Centigrade)? Continue to boil the water until it has evaporated. Since the water remains cold until all the ice has melted and the water never goes over 212° F., though heat is continuously applied to it, it is seen that energy (heat) is absorbed (expended) when water passes from a solid to a liquid and from a liquid to a gaseous state. These changes are physical changes: water is water (H_2O) whether as ice, as liquid water, or as water vapor.

Notes: Write up the result of this experiment.

Experiment b. Substances in solution.

Apparatus and material: Water; a large vessel; a cup; a soluble dye, such as eosin.

Procedure: In a quart of water dissolve a bit of eosin equal in amount to a grain of corn. The entire quart of water is colored. Pour a cupful of this solution into a quart of clear water and dilute a cupful of this second solution in the same manner. Continue the dilution until there is only a faint trace of color. In each successive dilution the particles of eosin

are separated farther and farther apart, but each particle is still eosin.

Notes: Define physical change and give examples.

EXERCISE 26. CHEMICAL CHANGES. (DEMONSTRATION)

Experiment a. Synthesis of water (synthesis = a putting together).

Apparatus and material: The apparatus shown in Fig. 8, which shows a hydrogen generator and a means of collecting

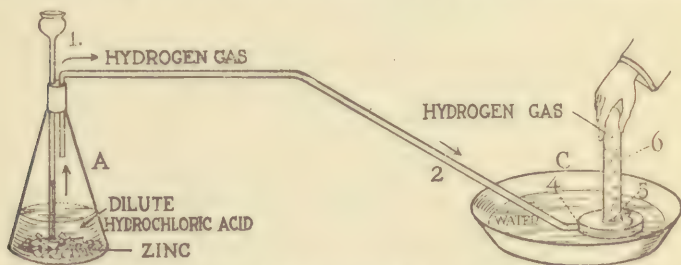


FIG. 8. Hydrogen generator. *A*, Erlenmeyer flask; *C*, shallow vessel of water; 1, thistle tube, to facilitate pouring the hydrochloric acid solution over the zinc; 2, delivery tube; 3, candy-jar lid, which facilitates collecting of gas; 4, a notch in the lid for inserting the delivery tube; 5, hole in lid; 6, test tube or bottle. The test tube is filled with water and inverted over the hole (5) in the lid. The gas bubbles up into the tube, displacing the water.

gas under water; test tubes; a short glass tube drawn to a point; a short rubber tube for making a connection. (This apparatus requires some time to set up at first, but it may be cleaned and set aside for use year after year. In larger high schools the demonstration may be made to advantage in co-operation with the Department of Chemistry.)

Procedure (a): The preparation and collection of hydrogen. Set up the apparatus for producing hydrogen as shown in Fig. 8 (unless a Kipp's generator is available). The hy-

drochloric acid should not be poured over the zinc until everything else is ready. The thistle tube facilitates the pouring of the acid into the flask. Gases may be collected under water in the following manner: The bottle or test tube to contain the gas is filled with water and inverted in a shallow vessel also containing water. The delivery tube should end in the water of the shallow vessel. The gas is collected by allowing it to bubble into the inverted bottle. Take the tin lid of a candy jar and cut a circular hole about 1 inch in diameter in the center, and into the edge cut a notch about $\frac{1}{2}$ inch deep. Place the lid, round hole up, in the bottom of the vessel of water. Run the delivery tube through the notch of the lid so that the gas as it is expelled from the apparatus will bubble up through the hole in the center of the lid. The bottle to contain the gas is filled with water and inverted over the hole in the lid. Gas bubbling up out of the round hole of the tin lid will pass into the bottle, displacing the water.

When everything is ready, add the acid to the zinc. Hydrogen gas is generated at once.

Caution: A mixture of hydrogen and oxygen is explosive, but pure hydrogen gas will burn with a steady flame. Allow the gas to bubble for ten minutes. Then test the gas as follows: Collect a test tube of the gas. Hold the tube mantle down in a towel and place a lighted match at the mouth of the tube. If a slight explosion results, the hydrogen is not yet pure; if, on the contrary, the gas burns steadily on down the tube, the gas is pure and you may proceed with the next experiment.

Procedure (b): The hydrogen flame and formation of water. When the gas coming from the generator is pure (as shown by its burning steadily and not exploding), attach to the delivery tube, by means of a rubber-tube connection, a

glass tube drawn out to a point. Apply a match to this point, and watch the gas burn. Hold a glass rod in the flame to test the heat.

To show that water is formed when the gas burns, hold a cold dry piece of glass or a polished piece of metal to the flame and note the water condensed thereon. Water is formed (synthesized) by a union of the hydrogen of the gen-

erator and oxygen from the air. The synthesis of water from hydrogen and oxygen involves a chemical change.

Notes: Describe a method of producing water from hydrogen and oxygen.

Experiment b. Analysis of water (analysis = a tearing apart).

Apparatus and material: The apparatus for the decomposition of water, shown in Fig. 9; a 10 % solution of sulfuric acid in water; three or more dry cells and several pieces of wire.

Caution: In mixing strong sulfuric acid and water always pour the acid into the water,

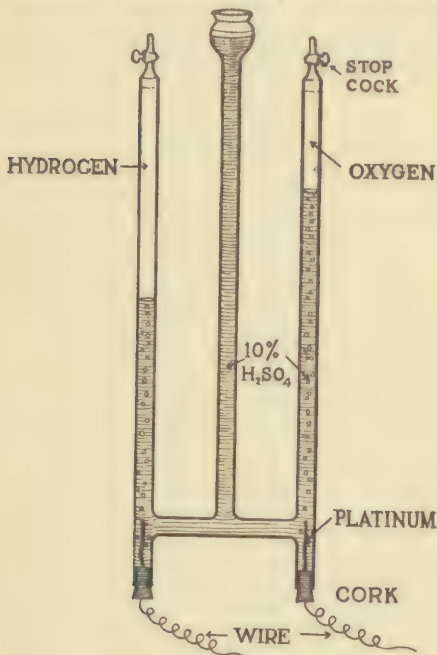


FIG. 9. Apparatus for decomposition of water. The tubes are filled with 10 % sulfuric acid, the stop-cocks are closed, and a current of electricity is passed through the wires and the solution. Water is decomposed into hydrogen and oxygen in the proportion of two volumes of hydrogen to one volume of oxygen.

never the water into the acid. As heat is generated by the mixture, and as heat may break the glass container, pour the acid into the water a little at a time, allowing the solution to cool at intervals.

Procedure: Set up the apparatus as shown. Fill the tubes with the dilute solution of sulfuric acid. Close the stopcocks at the top of the tubes. Connect the wires from the battery with the electrodes in the tubes. A current of electricity will pass through the solution and will cause the water to split into two parts of hydrogen and one of oxygen. As each will collect separately in one of the tubes, the quantity of each gas can be read off.

Notes: Sketch the apparatus used in this experiment. Hydrogen and oxygen are elements; water is a compound. Draw a diagram of an atom of hydrogen as in Ritchie, Fig. 44. Draw a diagram of an atom of oxygen. Draw a diagram of a molecule of hydrogen (compare with a molecule of iron, Ritchie, Fig. 43). Draw a diagram of a molecule of oxygen. Draw a diagram of a molecule of water. Can we speak of an atom of water? How many atoms in every molecule of an element? Of how many elements is water composed? How many atoms make up a molecule of water?

Experiment c. Synthesis of sulfid of iron.

Apparatus and material: A teaspoonful of iron filings; a like quantity of powdered sulfur; a test tube; a Bunsen burner.

Procedure: Examine the iron and the sulfur. Note their color, weight, hardness, and other properties. Mix equal measures of iron filings and sulfur in a test tube and heat gradually until red hot. Allow the mass to cool. Break the test tube and examine the new compound, iron sulfid, the result of the union of iron and sulfur.

Notes: Sketch a diagram of a molecule of iron (Ritchie, Fig. 43). Using a pentagon to represent an atom of sulfur, draw the diagram

of a molecule of sulfur. In a molecule of iron sulfid there are two atoms of iron and three of sulfur. Draw the diagram of a molecule of iron sulfid.

Experiment d. Analysis of oxid of mercury.

Material: A teaspoonful of oxid of mercury; a test tube; a Bunsen burner; a small splinter of wood.

Procedure: Heat the oxid of mercury in a test tube over a flame. Oxygen is driven off from the compound. Heat the end of a splinter of wood until it glows. Thrust the glowing splinter into the test tube. The splinter bursts into flame, showing that oxygen is present in the tube.

Notes: What is the source of oxygen in this experiment? Show how this illustrates chemical change.

Experiment e. Synthesis of oxygen with other elements: (combustion).

Apparatus and material: The apparatus shown in Fig. 10 (the potassium chlorate and the black oxid of manganese, from which the oxygen is to be generated, should be thoroughly mixed); a piece of picture wire; sulfur about the size of a grain of rice; a splinter of wood 5 or 6 inches long; three wide-mouthed bottles; three pieces of cardboard.



FIG. 10. Oxygen generator. The delivery tube and the apparatus for collecting gas are the same as in Fig. 8. Oxygen is driven off from the potassium chlorate and the black oxid of manganese by means of heat.

Procedure: When ready to collect oxygen, place the test tube over the flame. Oxygen will be driven through the delivery tube. Allow it to bubble into the water of the collecting pan until all the air originally in the test tube and the delivery tube has been driven out and replaced by relatively pure oxygen. The gas may then be collected over the hole in the candy-jar lid as directed for hydrogen. Fill the three wide-mouthed bottles or jars with the gas. Cover the mouths of the bottles with the pieces of cardboard and set them on the table ready for use in the following experiments:

(a) Burning wood in pure oxygen. Heat a splinter of wood in a flame until it glows. Thrust the glowing splinter into one of the bottles of oxygen. What is the result? In combustion of wood, oxygen unites with the carbon in the wood, forming carbon dioxid (CO_2) and with the oxygen, forming water (H_2O).

(b) Burning a piece of iron picture-wire in oxygen. Wind the frazzled end of the picture wire about a small piece of sulfur and light the sulfur in a flame. Then quickly plunge the wire into a bottle of oxygen. The wire will burn with a white light. Note the end of the wire fused by the heat and the black oxid of iron covering the wire.

Notes: Draw a diagram of a molecule of CO_2 (Ritchie, Fig. 45). Iron oxid contains two atoms of iron and three of oxygen. Make a diagram of a molecule of iron oxid. Define *oxidation*.

Review Exercise 1. All foods that can furnish the body heat and energy for work contain carbon. What happens to the food in the body when heat is produced? How can you show that organic foods contain carbon? Discuss the subject further after studying Ritchie, pages 83, 84, 114, 115, 160, and especially pages 347 and 348.

EXERCISE 27. TESTING COMPOSITION OF FOODS. PROPORTION
OF WATER IN FOODS. (CLASS WORK)

Apparatus and material: Scales; 15 to 20 g. each of potato, meat, and corn bread; an evaporating dish.

Procedure: Weigh small pieces of potato, meat, and corn bread. Evaporate them to dryness by slow heat; after which, weigh them again.

Notes: Calculate the percentage of water in potato, meat, and corn bread. Compare your result with table, Ritchie, page 350.

EXERCISE 28. COMPOSITION OF WATER. (CLASS WORK)

Apparatus and material: A test tube; a teaspoonful of starch.

Procedure: Dry the starch by slow heat. All free water should now have been removed. Place some of the dry starch in a test tube and heat it over a flame until the starch is charred. Note the *water* which condenses along the sides of the tube, especially near the mouth. The black substance in the bottom of the tube is *carbon*.

Explanation: The water calculated in the preceding exercise (27) exists in the food as water and may be removed by evaporation. In this exercise, on the contrary, the water driven off by heat is water of composition, *i.e.* it is originally a part of the molecule of starch. In all carbohydrates, hydrogen and oxygen exist in the molecule in the proportion 2:1, as in water (compare grape sugar, $C_6H_{12}O_6$; cane sugar, $C_{12}H_{22}O_{11}$; starch, $C_6H_{10}O_5$). In this experiment starch is broken up into carbon and water by heat. Study the following equation: $n C_6H_{10}O_5 = 6 C + 5 H_2O$.

Notes: Describe the physical and the chemical changes involved in Exercises 27 and 28.

EXERCISE 29. IODINE TEST FOR STARCH. (CLASS WORK)

Experiment a. Preparation of starch paste.

Apparatus and material: A beaker or a tin cup; 100 c.c. of water; two teaspoonfuls of starch.

Procedure: Boil a mixture of water and starch. A thin opalescent "solution" results. This will be referred to in the following exercises as *starch paste*.

Experiment b. Effect of iodine on starch.

Material: Test tubes; iodine solution; a glass rod or pipette; starch paste; potato; apple; and other substances to be tested.

Procedure: To a quantity of starch paste in a test tube add a drop of iodine. If the color of the starch paste is very dark, dilute it with water until a bright blue color is seen.

Add iodine solution to raw potato, cooked potato, bread, apple, cotton, sugar solution, or other substance which you desire to test.

Notes: Write up this experiment according to the outline given on page 40.

EXERCISE 30. TEST FOR GRAPE SUGAR, DEXTROSE, OR GLUCOSE. (CLASS WORK)

Apparatus and material: Test tubes; Fehling's solution; a solution of grape sugar made by dissolving 10 g. of cheap stick candy in 100 c.c. of water; solution of cane sugar made by dissolving one teaspoonful of granulated sugar in 100 c.c. of water; a half cup of sweet milk; a test-tubeful of starch paste. (Label each solution carefully.)

Procedure: Pour a small quantity of the grape sugar solution into a test tube (to the depth of one half inch); add twice that quantity of Fehling's solution. Boil the mixture over a

flame (gently at first). The red color indicates that a "reducing" sugar is present; in this case it is grape sugar. This test for sugar will be referred to below as *Fehling's test*.

Try this test on a small quantity of sweet milk in the same manner. Sweet milk contains milk sugar, which is also a reducing sugar, as is proved by the red color produced in this experiment. We shall see below that malt sugar, found in the mouth after digestion of starch by saliva (Exercise 36), is also a reducing sugar.

Try Fehling's test on a solution of cane sugar; on starch paste; no reduction (*i.e.* no red color) occurs.

Notes: Write up these experiments.¹

EXERCISE 31. TESTS FOR PROTEINS. (CLASS WORK)

Experiment a. Preparation of albumen solution.

Apparatus and material: The white of an egg; 200 c.c. of water; an egg beater; a glass jar.

Procedure: Beat up the white of an egg until it will "pour," and add it to 200 c.c. of water. This solution is a convenient form to use in demonstrating the reactions of protein.

Experiment b. Orange color test for protein.

Apparatus and material: Test tubes; albumen solution; strong nitric acid; ammonia solution.

Procedure: Add a few drops of nitric acid to a small quantity of albumen solution in a test tube; a white precipitate of protein results. Heat the mixture; the precipitate becomes yellow. Cool the test tube and add ammonia, a few drops at a time; the precipitate becomes orange, which in-

¹All experiments should be written up according to instructions given in the chapter on How to use this Manual.

icates the presence of protein. This test is called the *xanthoproteic test*.

Notes: Write up this experiment.

Experiment c. Violet color test.

Apparatus and material: Test tubes; albumen solution; a 5 % solution of sodium hydroxid; a 10 % solution of copper sulfate.

Procedure: To a quantity of the albumen solution add 10 drops of sodium hydroxid solution. Shake the mixture. Add one drop of the copper sulfate solution and shake the mixture again; then add a second and a third drop in like manner. The violet color indicates protein. This test is called the *biuret test*.

Notes: Write up this experiment.

Experiment d. Problem.

Apparatus and material: Same as those in **b**, except the albumen solution; instead of this use a piece of finger nail.

Procedure: Apply the xanthoproteic test (**b**, above) to the piece of finger nail. Is the finger nail composed of a substance like protein?

Notes: Write up this experiment.

EXERCISE 32. TESTS OF VARIOUS FOODS. (CLASS WORK)

Experiment a. Wheat flour.

Apparatus and material: Those needed in the test for starch (Exercise 29), for sugar (Exercise 30), for protein (Exercise 31, **b**); two tablespoonfuls of wheat flour; a piece of cheesecloth about the size of a small handkerchief for each pupil; water.

Procedure: Moisten two tablespoonfuls of wheat flour so as to make a dough. Place an exact half of this aside for comparison later. Place the other half in a muslin or cheese-cloth sack (or use a rag brought together like a sack) and wash out of the flour all the starch possible, using many changes of wash water. At intervals test the wash water for classes of foods. After a time, *gluten*, a kind of protein, will be left in the rag. What are the characteristics of gluten? Apply the xanthoproteic test to it. What is the result?

Notes: Write up this experiment, giving results in full. Estimate the proportion of gluten to starch in flour. Compare your results with those given for the solid portion of white bread. (See table, Ritchie, page 350.)

Experiment b. Milk.

Apparatus and material: Those needed for making the test for sugar and for protein; a pint of sweet milk; a shallow vessel; microscope; slides and cover glasses.

Procedure: (1) Test the sweet milk for sugar. (2) Allow a test-tubeful of milk to stand until the cream rises. To what class of foods does cream belong? (3) Mount a drop of milk on a slide, and observe it under the microscope. Note the numerous oil globules. (4) Pour some of the milk into a vessel and set it in a warm place until it sours or "clabbers." Test the curd. What class of food is it composed of? Taste the whey; it is sour. The acid which makes it sour is lactic acid, which is produced from the milk sugar by bacteria.

Notes: Write up these experiments. State why you think skim milk to be a wholesome, nutritious food.

Experiment c. Testing various other foods for classes of foods.

Material and procedure: Any food may be tested for sugar, starch, or protein, as desired: raisins, apples, potatoes, beans, bananas, etc. Find out whether good cane sugar or the cheaper grape sugar is used in certain cakes, bonbons, and the like.

Notes: Make a record of the results of these tests.

EXERCISE 33. PROCESSES OF DIGESTION. THE NEED OF DIGESTION. (CLASS WORK)

Experiment a. Soluble and insoluble defined.

Apparatus and material: Three tumblers of water; half a teaspoonful of salt, of clean sand, and of starch; a sheet of filter paper; a funnel.

Procedure: Perform the experiment as directed (Ritchie, page 110). Instead of filtering the liquids as described, a funnel may be used to hold the filter paper. It will be found that a piece of filter paper folded as in Ritchie, Fig. 59, will fit perfectly into a funnel, whereas it does not fit into a tumbler. Note from the figure how the folded paper is opened to fit the funnel: three thicknesses of the paper on one side and one thickness on the other. Vary the experiment by placing salt in one glass of water and starch in another. Set them aside for a day. Has the starch been dissolved?

Notes: Write up this experiment; define soluble and insoluble in your own words.

Experiment b. Diffusion.

Apparatus and material: A lump of potassium bichromate or copper sulfate; a tall glass jar.

Procedure: Place a lump of potassium bichromate or copper sulfate in the bottom of a tall jar. Gently pour water into the jar. Set it aside in a quiet place. Note the diffusion of the salt into the liquid. Substances in solution diffuse from where they are abundant to where they are less abundant.

Notes: Describe this experiment and apply the principle to Ritchie, Fig. 74.

Experiment c. Diffusion through a membrane. (Demonstration.)

Apparatus and material: 100 c.c. of starch paste (see Exercise 29, a); 100 c.c. of grape sugar solution (Exercise 30); two pieces of parchment tubing, each 8 inches long; a string; two quart jars of water.

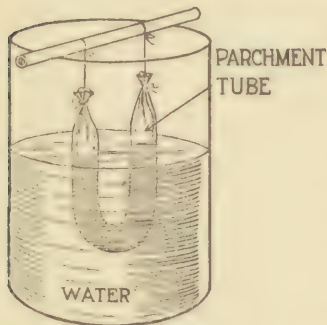


FIG. 11. Sausage diffusion tube. See Exercise 33, c.

Procedure: Soak two pieces of parchment tubing in water to soften them. Tie up one end of each tube. Fill one tube with the solution of grape sugar and the other with starch paste; then tie up the other ends of the tubes like a sausage, and hang the tubes in the jars of water.

We may now call the tubes "sausage diffusion tubes" (Fig. 11). Set the jars aside for 24 or 48 hours. At the end of either period test the water of one jar for sugar, the water of the other for starch. Has the sugar diffused through the tube into the surrounding water? Has the starch diffused through?

Suggestion: The teacher may set up the experiment and have each pupil test the water in the jars for himself.

Notes : Sketch the apparatus here used, and indicate the results in the drawing. What kind of substances only will pass through a membrane ? Study Ritchie, Fig. 60. The foods that pass into the cell and the wastes that pass out must pass through the membrane surrounding the cell. Study Ritchie, Fig. 76. Here it is seen that food absorbed by the blood from the intestine must pass through a membrane made up of cells. Apply the principle learned in the experiment described above to the absorption of food. State why food must be digested. Define digestion of food.

Experiments d. Osmosis.

Suggestion : The exercises given under this head may be assigned to different pupils, or may be demonstrated by the teacher. Experiments (4) or (5) may be substituted for (2).

(1) Osmosis through the membrane of an egg.

Apparatus and material : An egg ; a glass or a beaker containing 5 % hydrochloric acid ; a glass containing pure water.

Procedure : Immerse the egg over night in dilute hydrochloric acid solution to remove the shell. Then place the egg in water and allow it to stand for several days. Observe the increased size of the egg, which must now be handled with care.

Explanation : The swelling of the egg is due to the fact that water has passed into it, thus putting the contents of the egg under pressure. The water diffuses into the egg because water is "less abundant" within the egg ; that is, the solution within is *more dense* than the "solution" without, there being nothing in solution in the water on the outside. This causes a flow of water inward through the membrane. This phenomenon is called osmosis.

Notes : Write up this experiment.

(2) Further proof of diffusion of water into an egg.

Apparatus and material: A jar and a bottle as shown in Fig. 12; an egg; a glass tube or straw; sealing wax; a support for glass tube.

Procedure: Carefully pick the shell from the large end of an egg, taking care not to break the membrane under the shell, or the egg will be useless for the experiment. Drill a hole into the small end of the egg, and into this push a long straw or a glass tube about a foot long down to the yolk. If a glass tube is used, it must be supported. Wax the tubing in place so as to make the joint of egg and tube water-tight to prevent the contents of the egg from leaking out. Support the egg, large end down, in water, as shown in Fig. 12. Observe what follows. If the membrane of the egg is not broken, osmosis will take place, and the contents of the egg will rise in the tube.

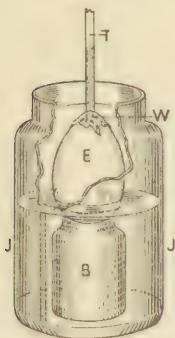


FIG. 12. Apparatus used to show diffusion through an egg membrane. (See Exercise 33, d.) J, jar of water; B, bottle; E, egg; T, glass tube; W, wax to seal the tube to the egg.

Notes: Explain this experiment.

(3) Osmosis through the skin of prunes.
(May be done at home.)

Apparatus and material: A dozen dried prunes; a glass of water; a glass containing enough sirup to cover six prunes.

Procedure: Place six prunes in the glass of water and six in the sirup. Observe the changes that the prunes undergo in 24 hours. If desired, the experiment may be continued by removing the prunes from the water at the end of 24 hours and placing them in the sirup for a period of time.

Notes: In the light of the explanation given under the experiment

(1) above, explain the changes which the prunes undergo when surrounded by water and by sirup.

(4) Osmosis through a carrot.

Apparatus and material: A carrot; a brace and bit ($\frac{1}{2}$ - or $\frac{3}{4}$ -inch bit); a one-hole stopper to fit a $\frac{1}{2}$ -inch hole; a glass tube to fit the hole in the stopper; sealing wax; a drop of red ink; strong sugar solution; a vessel of water.

Procedure: Cut off the leaves of a carrot, but do not injure the skin of the carrot. Bore a half-inch hole in the top or crown of the carrot, making the hollow as deep as possible. Do not break the skin of the carrot at any point. Fill the cavity with the sugar solution, to which has been added a drop of red ink. Fit the glass tube in the hole in the stopper, insert the stopper, and seal the joint with sealing wax. Scrape the skin from the lower end of the carrot and stand it in water, supporting it if necessary. Observe what takes place.

Notes: Explain this experiment.

(5) Osmosis through a parchment tube or a "diffusion shell."

Apparatus and material: A diffusion shell; a thistle tube; a strong cord; a quart vessel of water; 10 % solution of molasses in water; support with clamps.

Procedure: Fill the diffusion shell with the molasses solution to overflowing. Force the large end of the thistle tube into the diffusion shell to such a distance that the molasses solution rises in the stem of the thistle tube. Make a watertight joint between the diffusion shell and the tube by means of a stout cord. Set the shell in water and support it. It is essential for the success of the experiment that there be no leak between the diffusion shell and the thistle tube.

Notes: Explain this experiment.

EXERCISE 34. MORE READY SOLUBILITY OF FINE PARTICLES.
(CLASS WORK)

Experiment. Limestone changed chemically.

Apparatus and material: A lump of salt; some finely powdered salt; a lump of limestone (or marble); two beakers of water; two beakers of 2 % hydrochloric acid.

Procedure: (a) Place the lump of salt in one scalepan and in the other the same weight of powdered salt. Put the lump and the powder into beakers of water. Which dissolves the more rapidly? (b) Weigh out a lump of limestone and a quantity of powdered limestone in the same manner. Put each in a beaker of dilute hydrochloric acid. Which dissolves faster and why?

Notes: Apply the principle derived from these experiments to the advantages of chewing. (See also Exercise 43.)

In the preceding experiment the limestone is changed chemically by the acid so that it is rendered soluble.

EXERCISE 35. CHEMICAL DIGESTION. (CLASS WORK)

Experiment a. Cane sugar changed chemically.

Apparatus and material: Test tubes; a solution of a table-spoonful of sugar in 50 c.c. of water; 10 % hydrochloric acid; Fehling's solution.

Procedure: Add 15 drops of the acid to 5 c.c. of the sugar solution in a test tube. Boil the mixture for 10 minutes. Make the test for grape sugar with Fehling's solution. Use enough of the Fehling's solution to make the mixture distinctly alkaline. The acid and the heat have changed the cane sugar; they have split the molecule of cane sugar to two of grape sugar as follows (see Ritchie, page 113):



Notes: Write up this experiment.

Experiment b. Starch changed chemically.

Apparatus and material: Test tube; starch paste; 10% hydrochloric acid; tin cup of water.

Procedure: Add 10 drops of the acid to 5 c.c. of starch paste in a test tube and boil the mixture for 15 or 20 minutes. This is best done by setting the test tube in the cup of water, thus improvising a double boiler. Test the boiled mixture for sugar by Fehling's test.

Notes: Write up this experiment.

Explanation: Experiments **a** and **b** above merely illustrate chemical changes. The changes are brought about by heat and acid. The changes are, therefore, similar to but not identical with digestion or chemical changes of food in the body. Digestion in the body is not brought about by acid and high degree of heat, but by *enzymes*. (See Ritchie, page 112.) Exercises 36 and 37 below show digestion by enzymes.

EXERCISE 36. DIGESTION OF STARCH BY SALIVA. (CLASS WORK)

Apparatus and material: Test tubes; a quantity of saliva collected in a bottle and filtered (see Exercise 33, **a**, for method of filtering); three test tubes containing starch paste; a vessel containing a freezing mixture of cracked ice and salt; Fehling's solution.

Suggestion: Several pupils may work together to advantage in each experiment.

Procedure: (a) To test tube No. 1 of starch paste, add 2-3 c.c. of saliva. Let a pupil hold the test tube in his hand

so as to keep it at body temperature. (b) Boil a test tubeful of saliva. To test tube No. 2 of starch paste add 2 c.c. of the boiled saliva. Hold this in the hand likewise to keep it warm. (c) Place a test tube containing saliva in the freezing mixture; also test tube No. 3 of starch paste. When both are cold, add 2 c.c. of cold saliva to the cold starch paste. Keep the mixture cold.

After 15 minutes, test a sample from each test tube (Nos. 1, 2, and 3) for sugar, using Fehling's solution. Sugar is found only in which test tube?

Notes: Describe this experiment. What conditions are unfavorable to digestion of starch by saliva? (Digestion is due to enzymes; in this case the enzyme is *ptyalin* of saliva. Heat destroys the enzyme and cold retards its action.)

EXERCISE 37. THE DIGESTION OF PROTEIN BY GASTRIC JUICE. (CLASS WORK)

Apparatus and material: (1) Tubes of coagulated egg-white prepared as follows: place a number of pieces of small glass tubing about three inches in length in a test tube and pour over them the beaten white of an egg (albumen) (Fig. 13, A). Be sure that the glass tubes become filled with the albumen. Now set the test tube in a tin cup of water and bring this to a boil, thus coagulating (hardening) the albumen. Remove the glass tubes, now filled with solid albumen, from the test tube and clean them on the outer surface. Break them

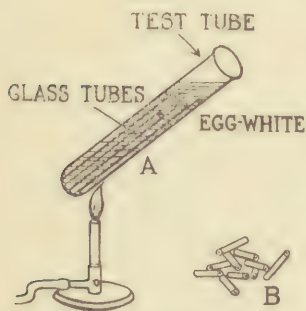


FIG. 13. A, apparatus needed to fill glass tubes with coagulated egg-white; B, glass tubes filled with coagulated egg-white and broken into three-fourths inch lengths.

into $\frac{3}{4}$ -inch lengths (Fig. 13, B). The solid albumen should now fill the short tubes flush with the ends. Any digestion of the albumen in the experiment below can be readily detected.

(2) Artificial gastric juice prepared by dissolving a teaspoonful of pepsin in 1000 c.c. of $\frac{3}{4}\%$ of hydrochloric acid. The weak acid solution is best made by adding $7\frac{1}{2}$ c.c. of strong hydrochloric acid to 1000 c. c. of distilled water.

Procedure: Place a tube of hardened albumen in a test tube and fill the test tube half full or more with artificial gastric juice. Set the test tube aside in a warm place, trying to keep it at about the temperature of the body (about 100° F.). The digestion of the protein can be readily observed in the glass tubes.

Notes: Write up this experiment. Compare with Exercise 36.

SECTION IV. ANATOMY OF THE DIGESTIVE ORGANS

EXERCISE 38. GENERAL VIEW OF THE VISCERA. (DEMONSTRATION)

Experiment a. Preparation of the animal.

Apparatus and material: Earthenware jar with lid, or airtight box; chloroform; cat (or rabbit or rat); pins; dissecting board.

Suggestion: In order to understand the structure of the organs it is necessary to see them in the body of an animal. It is best to use a mammal, such as a cat or a rabbit. The description here given applies particularly to a cat, but will suffice for the study of a rabbit or even a rat. It is not necessary to inject into the animal any fluid, such as formaldehyde, for a study of the viscera, as the specimen need not be kept for more than a day or two.

Procedure: Lay the animal, when killed, back down, on a dissecting board. Spread it out by tying the legs to the corners of the board. The animal is now ready for dissection as described under **b** below.

Notes: Describe how an animal may be humanely prepared for dissection.

Experiment b. Dissection of the cat.

Apparatus and material: The animal prepared as in **a**; dissecting instruments.

Procedure: Make a longitudinal incision in the skin from the pubis to the lower jaw; then a circular incision around the abdomen. Separate the skin from the underlying parts and pin it back. Note the glistening connective tissue under the skin. Now open the body cavity, cutting through the muscular wall with a pair of scissors. Note the layers of muscles in the body wall. What are their functions? Continue the incision forward through the sternum, using strong

scissors or "bone forceps" to cut through the bone. Note the diaphragm, the muscular partition of the body cavity (Ritchie, Figs. 8-10). What is the name of the anterior part of the cavity? the posterior part? (*Anterior* means towards the head; *posterior*, away from the head.)

a. Organs of the thoracic cavity:

The heart and the lungs are the conspicuous organs in the thoracic cavity. The heart is inclosed in a tough sac, the pericardium. If the specimen is a young animal, note the large pinkish thymus gland anterior to the heart and between the lungs. Note the smooth, moist covering of the lungs and a similar layer lining the thorax. Those two layers are the pleuræ (Ritchie, Fig. 82). Make out the larger blood vessels leaving and entering the heart. Expose the trachea or windpipe.

b. Organs of the abdominal cavity:

Posterior to the diaphragm are chiefly the digestive, urinary, and reproductive organs. Find the esophagus where it pierces the diaphragm. Note where it enters the *stomach*. This is the cardiac (nearest the heart) end of the stomach. The large blind sac of the stomach on the left side is called the *fundus*. (The guide line to the word "stomach" in Ritchie, Fig. 46, touches the fundus of the stomach.)

Where the stomach passes into the intestine there is a circular thickening, the *pylorus* (= gatekeeper), marked by a circular constriction on the outside (Ritchie, Fig. 48). What is the function of the pylorus?

The small intestine is easily followed from the stomach through its various convolutions to the large intestine. If both a cat and a rabbit are available, compare the length of the herbivorous and the carnivorous intestine. Why is the small intestine so long that it must be coiled up?

The large intestine receives the small intestine at right angles, leaving a blind sac, the cæcum, to which, in many animals, is attached the vermiform appendix (Ritchie, Fig. 46). There is no appendix apparent in the cat. Define appendicitis. (The suffix *-itis* added to words means inflammation.) The large intestine consists of the ascending, transverse, and descending colons, and the rectum, which ends in the anus.

The liver is a dark red body immediately posterior to the diaphragm. Note the lobes of the liver. Note how the liver fits up into the dome of the diaphragm and around the adjacent organs. Find the yellowish-green gall bladder. What is the function of this? The *pancreas* is a pink-red body consisting of two parts, one lying dorsal to the stomach and the other in the first loop of the small intestine. Can you find where the gall bladder and the pancreas empty into the small intestine? The bile duct may be made visible by squeezing the gall bladder and forcing bile into the duct. (Compare Ritchie, Fig. 48; in the human body the two ducts usually empty into the small intestine by a common duct.)

The spleen is a long, tongue-shaped, red-purple organ to the left of the stomach. The *omentum* is an apron-like structure covering the viscera. It is a part of the mesentery folds of connective tissue that support the organs. Spread out a portion of the intestines to show the mesentery. Note numerous knots of spongy tissue, the lymph nodes, in various parts of the mesentery.

The urinary organs consist of the kidneys, ureter, and bladder. Find the kidney on each side, close to the dorsal wall. It is often surrounded by fat. Leading from the kidney to the bladder is a narrow white strand. This is the duct called the ureter. (See Ritchie, Fig. 90.)

It has not escaped your notice that the organs are all smooth and moist. They are covered by a serous membrane, the *peritoneum*, which also lines the abdominal wall. (What is the meaning of the term peritonitis?) A serous membrane is one which lines a closed cavity of the body. It is smooth and secretes a kind of serum or lymph. Its function is to prevent friction. The pleuræ of the lungs, the pericardium of the heart, and the peritoneum of the abdomen are serous membranes. These can be pointed out at this time.

Notes: Make the observations as directed above, and sketch the various organs as seen in the specimen or specimens.

EXERCISE 39. INTERNAL STRUCTURE OF THE ORGANS. (DEMONSTRATION)

Apparatus and material: Dissecting trays containing a little water; pieces of the esophagus and the small intestine about one inch long, taken from the specimen used in Exercise 38; the stomach cut lengthwise into halves; dissecting instruments and pins; a hand lens.

Procedure: Slit the sections of the intestine and esophagus lengthwise. Pin these and the halves of the stomach on the bottom of the dissecting trays, under water. The pupils may now study the linings of the organs. Note the smooth lining of the esophagus and the folds, if any, of the other organs. With a hand lens examine the lining of the stomach to see if the fine pits, the openings of the gastric glands, are visible. (See Inner Surface of Stomach, Ritchie, Fig. 49.) Study the lining of the small intestine with care. Note the velvety appearance. (See Ritchie, Fig. 51.) Study the muscle layers of which the bulk of these organs is composed. Compare Ritchie, Figs. 49 and 51.

Notes : Describe the appearance of the inner lining of the esophagus, the stomach, and the intestine. Explain the velvety appearance of the inner surface of the intestine. Compare this with a coarse bath towel in appearance.

EXERCISE 40. THE MOUTH, THE THROAT, AND THE SALIVARY GLANDS. (DEMONSTRATION)

Experiment a. The salivary glands.

Apparatus and material: The cat used in the preceding exercises; dissecting instruments.

Procedure: Remove the skin from the head of the cat in the region of the ear. Salivary glands are seen below and behind the ear as pink, spongy masses just beneath the skin.

Notes : Sketch a side view of the head, showing nose, mouth, ear, and salivary glands.

Experiment b. Organs of the mouth and throat.

Apparatus and material: Same as in the preceding experiment.

Procedure : Cut away a little less than one half of the lower jaw of the cat, leaving the tongue in place. Dissect back, exposing the pharynx or the throat, laying bare the larynx or voice box. Pass a seeker, such as a knitting needle, into the esophagus, tracing it back into the stomach. A tonsil should be visible projecting out from the wall on the uninjured side just behind and below the root of the tongue. Find the tongue bone (hyoid) to which the tongue is attached. Note the posterior openings of the nasal passages. Press the soft palate forward, and with a broom straw or other seeker find a pair of slits in the upper wall of the throat. These are the openings of the Eustachian tubes leading to the middle ear. Leave the seekers in them so that they may be easily found

by the pupil. Demonstrate the fact that the throat is the crossing place of the food and air passages (Ritchie, Fig. 83).

Notes: Study Ritchie, Fig. 83, which represents a section through the head and neck of a man. Then draw a similar sketch showing a section through the head and neck of a cat.

Experiment c. The human mouth. (Home work.)

Apparatus and material: A hand mirror; one's own mouth.

Procedure: With the aid of a mirror, study your own mouth: lips, gums, teeth, tongue, cheeks, hard palate, soft palate, uvula (tip of soft palate), throat, tonsils, glottis (opening into larynx), and epiglottis (covering of the glottis). (See Ritchie, Fig. 83, and *The Human Body and its Enemies*, Fig. 94.)

Notes: Make a sketch of the open mouth.

EXERCISE 41. THE TONGUE AND THE TEETH. (CLASS WORK)

Experiment a. The tongue.

Apparatus and material: Tongue of a cat; hand lens; tongues of other animals; mirror; pupil's own tongue.

Procedure: (1) Study the tongue of the cat, using a hand lens if necessary. Make out the numerous tiny projections, called papillæ, which give the surface a rough appearance. Cut out a piece of the tongue. Of what tissue is it chiefly composed? (2) Study your own tongue with the aid of a mirror. (3) Observe the tongue of a lizard, a toad, a snake (Ritchie, page 104).

Notes: State the functions of the tongue; describe your own tongue.

Experiment b. The human teeth. (Home work.)

Apparatus and material: Hand mirror; one's own teeth.

Procedure: Study your own teeth with the aid of a mirror. Make out each kind according to Ritchie, Fig. 53. Note the two cusps or points on the bicuspid.

Notes: Sketch one of each kind of human tooth.

Experiment c. The teeth of other animals.

Material: Skulls of various animals; a crayfish; the crop of a chicken. The enterprising boys of the class will be glad to add to the collection from specimens of dry, bleached skeletons found in the woods or prepared as directed in Exercise 10, b.

Procedure: Study the teeth of rodents (such as squirrels, rats, etc.) with their prominent incisors; the teeth of herbivorous animals (such as horse, cow, etc.); the teeth of carnivorous animals (cats and dogs); the teeth of insectivorous animals (the bat); the teeth of fish.

An animal that has "teeth" in its "stomach" is the crayfish. Bring a live specimen to school, and keep it in an aquarium. Observe its manner of feeding. Kill a crayfish by chloroforming it. Cut away the entire dorsal wall of the animal, using a pair of scissors to do this. The intestine is thus exposed. Note the large stomach in the anterior end of the body cavity. Slit this open with a pair of scissors, and find the three grinding teeth in the stomach.

Bring to the laboratory the unopened crop of a chicken. Open the crop to show the pebbles it contains. How does the bird grind its food (not having teeth)?

Notes: Record your observations as time permits.

EXERCISE 42. FINER STRUCTURE OF THE DIGESTIVE ORGANS.
(CLASS WORK)

Experiment a. The structure of a tooth.

Apparatus and material: A human tooth (which may be obtained from a dentist's office); sealing wax; a block of wood; a file and a vise.

Procedure: Imbed a tooth in sealing wax. To do this, melt the wax in a flame and let about ten drops fall on the block of wood. Lay the tooth upon this mass of wax. Then allow more molten wax to drip over the tooth until it is completely imbedded. Place the block of wood in a vise, and file down tooth and wax to the pulp cavity of the tooth. The enamel, cement, dentine, and pulp cavity should now be plainly seen. Distinguish the crown, neck, and root of the tooth (Ritchie, Fig. 52).

Notes: Sketch a section of a tooth.

Experiment b. Cross section of the esophagus. (Demonstration.)

Apparatus and material: Microscope and prepared cross section of the esophagus.

Procedure: In the prepared section of the esophagus, make out with the microscope the mucous lining and the muscular walls. Note that the epithelium of the mucous membrane is several cells thick. The mucous membrane includes not only the epithelial layer, but also the underlying connective tissue layer.

Notes: Make a drawing of the lining of the esophagus.

Experiment c. Cross section of the stomach. (Demonstration.)

Apparatus and material: Microscope and prepared cross section of the stomach.

Procedure: The section of the stomach should show structures represented in Ritchie, Fig. 49. Note especially (1) the epithelial tissue of the mucous membrane only one cell thick; (2) the gastric glands, pockets of the mucous membrane dipping down into the wall of the stomach (study Ritchie, Figs. 47, 49, and 50, *B*); (3) the muscular wall consisting of a thicker layer of ring muscles within and a thinner layer of longitudinal muscles without.

Notes: Make a sketch of a portion of the wall of the stomach as seen.

Experiment d. Cross section of the small intestine. (Class work.)

Apparatus and material: Microscope and prepared cross section of the small intestine.

Procedure: The section should show glands (intestinal glands) similar to those of the stomach and similar muscular layers. The most interesting structures of the intestine, not possessed by the other organs, are the villi (Ritchie, Fig. 51; see also Fig. 76). Note the one-celled epithelial layer of the mucous membrane. The blood capillaries of the villi may or may not be visible.

Notes: Make a drawing representing several villi and intestinal glands of the intestine as seen under the microscope.

Experiment e. Glands. (Home work.)

Material: Ritchie, Figs. 47, 49, 50, 51, 54, 55, 76, 91, 93.

Procedure: It is inadvisable in an elementary course to study glands further with a microscope, since the structure of the liver, a salivary gland, or the pancreas is too complex to be appreciated from the sections. The illustrations in Ritchie should be studied with care. Note that a gland consists of

epithelial tissue arranged essentially as a pocket or a long tube. (Discuss Fig. 50.) This arrangement enables the gland to carry more secreting cells than it could if merely spread out like a pavement. Point out the secreting cells in Fig. 47. Note the blood vessels close to the cells. What does *secrete* mean? Whence do the working cells receive their material? Why are the blood vessels close to the cells? Copy Fig. 47, labeling the secreting cells. Figure 49, *B*, is a more nearly exact representation of a gastric gland. Note that the intestinal glands of Fig. 51 resemble the gastric glands of Fig. 49. Wherein are the villi like the glands? Wherein different? Compare Figs. 47 and 76. Gastric and intestinal glands are simple glands. The pancreas and the salivary glands and the liver are compound, for they consist of many simple parts united together. Study Fig. 54. What is the function of the ducts? Study Fig. 55. Note the duct. What parts of a salivary gland are like a simple gland? (Compare Fig. 47 and the individual parts of Fig. 55.) Compare *B* and *C* of Fig. 93. It should now be clear that all these glands consist of epithelial (pavement) tissue arranged in the form of tubes or tubular pockets. Draw a cross section of a gastric gland (Fig. 47) after Fig. 93, *C*. In the slide showing a cross section of the stomach, such cross sections as just drawn may perhaps be found.

How would a cross section through Fig. 49, *A*, along the line marked by the word Glands appear?

Notes : Answer the questions, and make the drawings as directed in the Procedure above.

SECTION V. DIETETICS

(To accompany Ritchie, Chapter X)

EXERCISE 43. ADVANTAGES OF CHEWING. (CLASS WORK)

Apparatus and material: Hard-boiled egg; cracker; Fehling's solution; test tubes; hand lens.

Procedure: (a) Chew a piece of hard-boiled white of egg for a short time; examine the lumps. Chew another piece for a long time; examine the fine particles of this mass with a hand lens. (b) Chew a cracker slightly; test the mass for sugar with Fehling's solution. Chew another portion until liquid; test this also for sugar. Which has the larger quantity of sugar as indicated by the color of the test?

Notes: Review Exercise 34. State the advantages of chewing food thoroughly.

EXERCISE 44. STARCH GRAINS. (DEMONSTRATION)

Apparatus and material: Microscope; slides and cover glasses; scalpel or other knife; raw potato; well-cooked potato.

Procedure: Cut each potato in two. Scrape a knife blade across the cut surfaces, raw and cooked, and smear the scrapings on slides. Add a drop of water and place a cover glass over the preparations. Study them with the microscope. Note the starch grains and the cells. Ritchie, Fig. 61, shows the appearance of the raw potato. The starch grains are more conspicuous than the glass-like cell walls about them. In the cooked potato the starch grains are swollen and broken and can hardly be distinguished as starch grains.

Notes: State the advantage of cooking vegetable foods.

EXERCISE 45. INTESTINAL PARASITES. (DEMONSTRATION)

Apparatus and material: Microscope; prepared slide showing trichina encysted in muscle of pig; specimens of tapeworm

and hookworm. A tapeworm may be secured from almost any physician; hookworms may be secured from physicians in many parts of the South.

Procedure: Examine a section of pork muscle showing trichina (Ritchie, Fig. 62). Examine specimens of tapeworm (Fig. 63) and hookworm (Ritchie, page 354). Learn all you can about these parasites which live in the human intestine.

Notes: Make a sketch of trichina found in pork. State why meat always be cooked. State how hookworm disease is spread and how it may be prevented.

EXERCISE 46. CLEANLINESS OF FOODS. (CLASS WORK)

Material: The dairies, restaurants, slaughterhouses, and grocery stores of your own town.

Procedure: Study Ritchie, pages 327-332. Consult also *Primer of Sanitation*, Hartman and Bibb's *The Human Body and its Enemies* (World Book Co.), and other sources in order to learn what the sanitary conditions of your town ought to be.

Make up a list of questions like the following, discuss the answers in class, and send committees on a tour of inspection where the answer is in doubt. Are the barns at the dairies clean? Are the milch cows free from tuberculosis? Is the milk drawn in wide open or narrowly open buckets? Are the milk vessels thoroughly cleaned and scalded before being used? Do any sick or convalescent persons handle the milk vessels at the dairy? Are the slaughterhouses screened or do they swarm with flies? Are the floors of the slaughterhouses water-tight or does blood run through the cracks to decay under the floor? Are the fruit stands screened? Do the flies promenade over the candy and fruit at the grocery or confectionery store? Does your town allow candies exposed

to the dust of the street to be sold? Are the barns and horse lots behind the shops kept clean or are they breeding places for flies? Does your baker, when on his round, handle alternately the harness of his horse and the bread you eat? Is the kitchen of the restaurant as clean as the dining room? Does your water supply come from deep, safe wells or from shallow wells? If it comes from surface streams, is it filtered before it is used?

Notes: Answer these and other similar questions; grade your town as to the sanitary conditions of its food supply on the basis of 100 representing perfection.

EXERCISE 47. ADULTERATION OF FOODS. (CLASS WORK)

Material: The report of your State Pure Food Commissioner or Food and Drug Commissioner, to be obtained by the teacher for the school.

Procedure and notes: Read the report and make a list of foods that are commonly adulterated. Make out and answer a list of questions similar to the following: How may milk be adulterated? How is it often preserved? How is the taste of decaying meat concealed? What preservatives are used in meats? How are vinegars adulterated? What is the difference between a good and a poor grade of molasses, and how is the latter made to look like the former?

EXERCISE 48. PATENT MEDICINES. (CLASS WORK)

Material: The report of the State Food and Drug Commissioner; labels on patent medicine bottles from the drug store. (According to the Food and Drugs Act the labels must state the presence of certain drugs in the contents of the bottle.)

Procedure: Appoint a committee to go to the drug stores and look over the labels on the bottles of the patent medicines on sale. Make the following lists:

(1) Medicines containing much alcohol. (Beer has 4-8 % ; wine, 15-20 % ; whisky, 30-50 %.)

(2) Medicines containing chloroform, laudanum, opium, morphine, codein, heroin, or other harmful drugs.

(3) A list of baby medicines containing harmful drugs.

(4) Find out what patent medicine labels give the term ethylic hydroxid for alcohol, trichlor methane for chloroform, and other misleading terms.

(5) Find out what drugs are contained in most headache remedies.

(6) Find out what soft drinks sold at soda fountains contain caffen.

Notes: The notes should contain at least the first three lists mentioned above.

SECTION VI. THE CIRCULATION

EXERCISE 49. THE BLOOD. (DEMONSTRATION)

Experiment a. Fresh human blood.

Apparatus and material: Microscope; four slides with cover glasses; 1 % acetic acid solution; a needle; a flame for sterilizing the needle (an alcohol lamp may be used).

Procedure: Draw a drop of blood in the following manner: Wrap a handkerchief tightly around the left thumb; bend the thumb so as to put the blood under pressure in the thumb. With a needle sterilized in a flame, puncture the skin above the nail of the thumb by a quick stab. Collect one drop of blood on glass slide No. 1 and quickly cover with a cover glass. Collect another drop of blood in a drop of 1 % acetic acid on slide No. 2. Collect a third drop on slide No. 3 and cover this with slide No. 4. Separate slides Nos. 3 and 4 after the drop of blood has spread, and lay them on the table to dry for use in the next exercise (**b**, below).

Make out the red and the white blood corpuscles on slide No. 1 — the red are of a yellowish tinge and are often arranged in series like stacked saucers (lower left-hand corner, Ritchie, Fig. 72). Note shape of red corpuscles as seen from edge (middle of Fig. 72) and in flat view (top and bottom of Fig. 72). The white blood corpuscles are much less numerous and are almost transparent and white when unstained. Slide No. 2 will show white corpuscles only, the red ones having been dissolved by the acetic acid.

Notes: Sketch the white and the red blood corpuscles as seen under the microscope. Represent the red corpuscles $\frac{1}{4}$ inch in diameter and the white corpuscles in proportion.

Experiment b. Stained blood.

Material: Slides Nos. 3 and 4 set out to dry in **a**; cover glasses; Wright's stain; microscope; a glass rod.

Procedure: Place a drop of Wright's stain on the dry blood film of slide No. 3 and slide No. 4. Leave it on for five minutes by the watch. Wash off the stain with distilled water. Wipe the lower surface of the slide dry, place a cover glass over the stained blood film (still wet), and study it under the microscope. Find white blood corpuscles with the nucleus stained blue as shown in Ritchie, Fig. 72.

If it is desired to preserve the stained preparation permanently, the slide should be allowed to dry perfectly in the air after staining. A drop of liquid Canada balsam is placed in the middle of the film of stained blood and a well-cleaned cover glass placed on the balsam. The balsam will gradually spread under the cover glass and bind the cover and slide together permanently.

Caution: Care should be taken not to get any balsam on the lens of the microscope. Should this happen, it may be removed with a rag or tuft of cotton soaked in xylol or chloroform. The balsam should be thin enough to spread readily under the cover glass. If too thick, add xylol.

Notes: Sketch white blood corpuscles, stained.

EXERCISE 50. THE CIRCULATION OF BLOOD IN A FROG OR A TADPOLE. (DEMONSTRATION)

Experiment a. Tadpole.

Apparatus and material: Microscope; a sheet of cork or thin board (a piece of shingle or a side of a cigar box), with a $\frac{1}{8}$ -inch hole near one end; thread; pins; a pithing needle; a tadpole or frog; glass slide; cotton; chloroform; dissecting instruments.

Procedure: If a tadpole is used, lay it on a slide and cover the "head" with wet cotton so as to prevent the es-

cape of the animal. Lay a cover glass over the tail, supporting it by small wads of paper or cotton so as to prevent crushing the tail. Fill vacant spaces around the tail under the cover glass with a drop of water.

If a frog is used, pith the animal, brain and spinal cord. To do this, kill the animal with chloroform. Find the joint between the head and trunk of the frog on the dorsal surface by bending the head up and down. Cut through the skin at this point with a scalpel. Now insert the pithing needle or stiff wire and run it forward into the brain, twisting the needle so as to destroy the brain; then run it backward into the neural canal of the spinal column so as to destroy the spinal cord. The frog is now ready for study. The blood will continue to circulate for some time.

Lay the animal on the board and spread the foot out over the hole, tying the toes apart with thread attached to pins. The web of the foot should be immediately over the hole in the board, and here the circulation may be observed through the microscope.

Note arteries, veins, and capillaries. (Arteries have the blood flowing from the forkings of the blood vessels; veins toward these points.) Note the continuous flow of the blood. Note the white blood corpuscles often clinging to the walls of the vessels and the red corpuscles flowing on in the middle of the stream. Note the size of capillaries in proportion to the size of corpuscles; the relative length of capillaries and the relative number of red to white corpuscles. Compare Ritchie, Figs. 65 and 69; also Figs. 74 and 76. Find other figures in the text which show that capillaries function to connect arteries and veins. What is the principal function of the capillaries? (See Fig. 74.)

Notes: Describe the circulation of blood in the capillaries.

EXERCISE 51. COLOR OF BLOOD. (CLASS WORK)

Apparatus and material: A living mouse, rat, or frog; test tubes; narrow glass tube; chloroform; dissecting instruments.

Procedure: Kill the animal which is to furnish the fresh blood. Remove the skin from the inner surface of the thigh and find an artery. Cut the artery and in a test tube collect the blood that flows from it. Note the color of the blood. With a straw or glass tube blow your breath (containing CO_2) through the blood. Note the change of color in the blood.

Notes: Describe and explain the differences in color between arterial and venous blood.

EXERCISE 52. THE CLOTTING OF BLOOD. (CLASS WORK)

Apparatus and material: An animal to furnish fresh blood; chloroform; dissecting instruments; a 5 % solution of sodium oxalate; ice; three test tubes.

Procedure: Kill the animal by chloroforming it and expose an artery as in the preceding exercise. Have ready for receiving the blood three test tubes. Test tube No. 1 should be cooled on ice (*e.g.* in the freezing mixture as described in Exercise 36). In test tube No. 2 place 2 c.c. of a 5 % solution of sodium oxalate. Test tube No. 3 is used without change. Collect 5-8 c.c. of blood in each test tube. Place No. 1 on ice as soon as the blood has been collected in it. The cold will keep the blood from clotting. Clotting does not occur in test tube No. 2. Sodium oxalate among other chemicals prevents clotting. Compare with the way amo squito prevents the clotting of the blood of its victim. The blood in test tube No. 3 clots as follows: the blood, at first liquid, soon becomes a solid mass; the tube may be inverted without

spilling the blood. Later, the clot (fibrin) separates from the straw-colored serum.

Notes: Describe the clotting of blood. How does the mosquito prevent the clotting of blood which he sucks from his victim? Why does a mosquito bite cause itching? How does a mosquito inject yellow fever or malarial germs into a person's blood?

EXERCISE 53. THE STRUCTURE OF THE HEART. (CLASS WORK)

Material: Obtain from a butcher the heart of a calf or sheep. Have the butcher remove the heart from the animal in such a way that the pericardium (membranous sac in which the heart is encased) remains intact and the blood vessels attached to the heart are left as long as possible. Soak the heart in 1% formaldehyde solution over night. Then preserve it in 5% formaldehyde. If the class is large, several specimens should be secured. These may be preserved from year to year. Other material needed are dissecting instruments, including seekers (darning needles or thin rods of wood); pins; a piece of wood 2 by 3 inches; cotton.

Procedure: (a) The principal blood vessels near the heart. Study Ritchie, Figs. 66 and 70, in connection with the heart before you. These illustrations represent the ventral view; the apex of the heart points to the left. Identify the left ventricle in the specimen; the apex is a part of the left ventricle. Lay the specimen on the dissecting board in a position to correspond to the figures in Ritchie. In this position almost the entire right ventricle is visible, only a portion of the other chambers being seen. Identify the right ventricle. Find the pulmonary artery. Find the right auricle and the vena cava ascending and the vena cava

descending, both entering the right auricle. Run seekers into the venæ cavæ. The largest artery is the aorta; it forms an arch anterior to the heart.

(b) The valves of the heart. Having identified the main divisions of the heart from without, slit open the right ventricle and the pulmonary artery, using a pair of scissors. Extend the incision into the wall of the auricle, opening this chamber also. Identify the tricuspid valves between the auricle and ventricle. The valves are flaps of connective tissue hanging down into the ventricles. Note the chordæ tendinæ (tendon-like cords) by which the margins of the valves are fastened to the wall of the ventricle. What is the function of the valves? Study Ritchie, Fig. 64, to answer this question. To what in Fig. 67 do the chordæ tendinæ correspond?

Since the tricuspid valve prevents the blood from gushing into the auricle, which way must it flow? What keeps the blood from flowing back into the ventricle when this relaxes? Find the semilunar valves of the pulmonary artery. Find the pockets as shown in Ritchie, Fig. 68. What name is applied to those valves in Ritchie, Fig. 64?

Turn the heart around, dorsal side up. Open the left ventricle and the aorta. Note the bicuspid valve between auricle and ventricle with its chordæ tendinæ. Note the semilunar valves (Fig. 68) at the mouth of the aorta. Find pulmonary veins entering the left auricle.

Pin labels to the specimens thus prepared, and let each pupil draw one side of the heart to show the structure.

A dissection of the base of the aorta or the pulmonary artery, as represented in Ritchie, Fig. 68, may well be mounted on a thin board and preserved for ready reference. Slit the artery at the base so as to bring the semilunar valves into

plain view, then cut out the base of the artery and pin it, or, better, tie it, well spread out, on a thin board of convenient size. A little cotton stuffed into the pocket-like valves will make them stand out more plainly. Preserve the preparation in 80% alcohol or 5% formalin.

Notes: Make a drawing of the right side of the heart, cut open lengthwise.

EXERCISE 54. TRACING THE COURSE OF THE BLOOD. (HOME WORK)

Material: Ritchie, Figs. 66 and 70; notes on the dissection of the heart.

Procedure and notes: After studying the heart, it should be easy with the aid of Ritchie, Figs. 66 and 70, and page 144 of the text to trace the course of the blood throughout the body. The teacher may now assign several problems, such as the following: Trace the blood from the left side of the heart through the head back to the left side; trace the blood from the right lung to the left lung; trace the blood from the right auricle to the left auricle; trace the blood through the liver by two partly different routes.

EXERCISE 55. THE BEATING OF THE HEART. (DEMONSTRATION)

Apparatus and material: Frog; chloroform; pithing needle; Ringer's solution; shallow vessel.

Procedure: Pith a frog as described in Exercise 50. Open the chest cavity. Immerse the frog in warm Ringer's solution. Observe the beating of the heart. Where does each beat begin (wave of contraction is indicated by paleness of part)?

Notes: Describe the beating of the frog's heart.

EXERCISE 56. THE LYMPH VESSELS OF THE INTESTINE.
(DEMONSTRATION)

Apparatus and material: Rat or young cat; chloroform; dissecting instruments.

Procedure: Feed a rat or a young cat with milk, cheese, or fat meat. Kill it with chloroform one hour after feeding. Open the abdominal cavity at once, and observe the white streams of lymph containing fat in the lacteals and lymph vessels which are found in the mesentery of the intestine. See Ritchie, Figs. 66 and 76; in these figures the lymph vessels are represented in black.

EXERCISE 57. DEMONSTRATING THE VALVES IN THE VEINS.
(HOME WORK)

Material: One's own hand.

Procedure: (See Ritchie, page 159.) Allow your hand to hang down, and press the forearm against the edge of the table. This makes the veins of the wrist or back of the hand stand out boldly. Press on a vein with one finger. On the side of the finger toward the heart, empty the vein by rubbing another finger along it. Does the blood flow back into the vein? On the other side of the finger that is pressing the vein, rub the blood away from the heart. Does the blood flow back into the vein? Explain. Now remove the first finger. Rub a vein downward toward the fingers. Can you find the place of a valve in the vein?

EXERCISE 58. THE HUMAN PULSE AND HEARTBEAT. (HOME WORK)

Apparatus and material: A watch; for (b) a handkerchief and a small, strong stick.

Procedure: (a) The pulse. The pulse is usually felt in the

radial artery on the thumb side of the wrist. The tips of the fingers should be used in feeling the pulse. Find the pulse also on the temple, in front of the ear, and under the knee.

(b) Bleeding. Study Figs. 135 and 136 and note where the arteries come close to the surface. Practice the application of the tourniquet as shown in Fig. 136, taking for granted that the artery of the wrist has been cut.

(c) Pulse rate. Count your pulse rate per minute after lying still for ten minutes; after sitting; after standing; after walking; after running or hopping. After the last count, sit down and find out how long it takes for the pulse rate to go back to the normal rate for the sitting posture. Why must the heart beat faster when we exercise? (Get the answer from Ritchie, Figs. 60, 74, and 81.)

(d) Heartbeat. Feel the heart "beat" between the fifth and sixth ribs a little to the left of the sternum. Apply the ear closely to this point in another person, and hear the two sounds of the heart. These are probably due to the closing of the bicuspid and tricuspid valves (causing the first sound) and the semilunar valves (causing the second sound).

Notes: Write up each of the experiments in this exercise, recording your results in full.

EXERCISE 59. WHY THE BLOOD FLOWS IN A STEADY STREAM IN THE CAPILLARIES. (DEMONSTRATION)

Experiment a. Elastic arteries are required for a steady stream.

Apparatus: Prepare the apparatus pictured in Fig. 14. This consists of glass tubing, soft elastic tubing, a large aspirator bulb, and a tumbler of water. The glass tip of *A* and *B* is made by drawing out a glass tube to a point

as fine as desired. To do this, heat the glass tube in the flame of a Bunsen burner. If gas is not available, the teacher may use a gasoline blow torch such as is used by plumbers. Heat the tube until it can be drawn out easily. To represent the left ventricle of the heart, an aspirator bulb of large size will do. This has a valve at each end; one might represent the bicuspid valve, the other the semilunar valve. Arrange the bulb so that when it is squeezed in the hand in imitation of the heartbeat (=contraction of the ventricle) the water

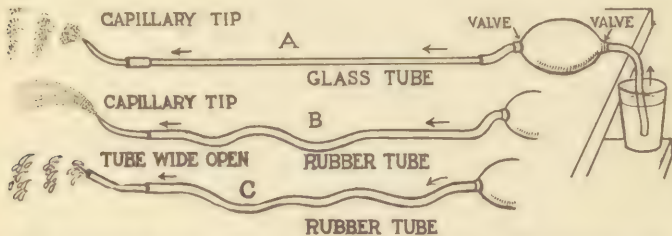


FIG. 14. Apparatus to illustrate experiments in Exercise 59. One aspirator bulb may be used in the three positions (*A*, *B*, and *C*). Water is pumped out of the tumbler into the tubes *A*, *B*, and *C* by squeezing the bulb with the hand. A steady stream flows from *B* only, which has a tube with flexible walls and a capillary tip.

(=blood) is sucked up out of the tumbler (see *A* of Fig. 14) through the bulb and into the tube. What does this tube represent? The fine point of the tip of *A* and *B* represents the capillaries.

Procedure: Place the bulb in connection with the glass tube as in *A*. Squeeze the bulb at regular intervals, say about once a second. The stream issuing from the tip always comes in jerks. Place the bulb as in *B*. Squeeze the bulb as before. At first the spray issues from the tip in spurts; but after the pressure is sufficient to distend the rubber tube (= artery) a steady stream issues. Feel the

“pulse.” These experiments show two things: (1) that there must be sufficient pressure to distend the arteries. (In case of great loss of blood, a normal salt solution is usually injected into the arteries to make up the volume of the blood.) (2) That the arteries must be elastic.

Experiment b. The resistance offered by the capillaries is essential for a steady stream.

Apparatus: Same as in a.

Procedure: Remove the capillary tube from *B* and replace it with an open tube as in *C*. Pump the water with the bulb. No steady stream is obtainable because the pressure cannot accumulate when there is no resistance at the outlet.

Experiment c. More energy is required to pump water into a tube with rigid walls than into an elastic tube.

Apparatus: Same as in a.

Procedure: Pump water first into the glass tube *A* and then into the rubber tube *B*, feeling the difference in the force required to pump water in the two positions. (See Ritchie, top of page 156.)

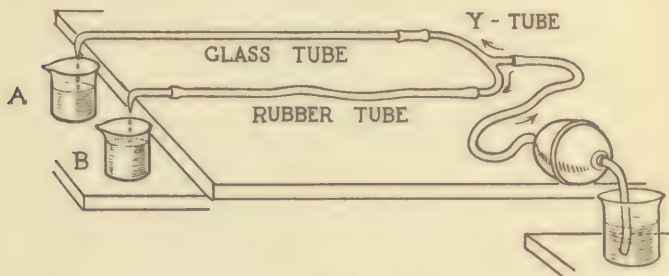


FIG. 15 Apparatus for Exercise 59, d. The rubber tube delivers more water than the rigid tube.

Experiment d. An elastic tube with elastic walls delivers more water than a similar tube with rigid walls.

Apparatus : As shown in Fig. 15, the two arms of the Y-tube are of the same size.

Procedure : With the aspirator bulb, pump water simultaneously into the glass tube and the rubber tube through the Y-tube. Measure the water delivered by the two tubes.

Notes : Write up the experiments performed in this exercise.

SECTION VII. RESPIRATION

EXERCISE 60. THE LUNGS AND THE AIR PASSAGES. (DEMONSTRATION)

Experiment a. The lungs.

Apparatus and material: A cat; chloroform; a killing jar or box; dissecting instruments; two pieces of glass tubing, each four inches long and a rubber tube to connect them; dissecting board.

Procedure: Kill the cat by chloroforming it. Stretch it out on a dissecting board, back down. Dissect the organs of respiration according to the following directions:

Remove the skin from the ventral surface of the body, and open the thoracic cavity as directed in Exercise 38. Cut away the muscles of the neck so as to expose the larynx, or voice box, and the trachea, or windpipe. These are readily recognized on account of the stiff rings of cartilage in their walls. Trace the air passages, beginning at the nose. Cut off the cartilaginous tip of the nose to see the irregular nasal passages. The posterior opening of the nasal passages into the throat have been noted previously (Exercise 40, b). Trace the trachea to its division into the two bronchi, which pass into the lungs. Now, to inflate the lungs, insert one of the short glass tubes into the trachea. Attach to this the other glass tube by means of the rubber connection in such a way that the rubber may be pinched together after the inflation of the lungs. Inflate the lungs by blowing through the glass tube.

Caution: When the lungs are inflated, the air in them is under pressure; if, therefore, the pressure from the breath is relieved, the air in the lungs is likely to rush out and blow mucus into the mouth of the experimenter. This can easily be avoided by pinching together the rubber connection before relieving the pressure.

Note the color of the lungs. Cut off a portion of one lobe of the lungs; air bubbles emerge from the cut bronchial tubes and air sacs. Place the portion cut off in water; it floats. Why?

Notes: Make a sketch of the lungs and the air passages.

Experiment b. The trachea, bronchi, and bronchial tubes.

Apparatus and material: The dissection made in a; microscope; a prepared slide of the trachea.

Procedure: Follow a bronchus into one of the lungs and dissect the lungs along one of the larger bronchial tubes as far as practicable. Study Ritchie, Fig. 84. Note in the dissection that the larynx is a box of cartilage. Open it and find the vocal cords. Compare with Ritchie, Figs. 85 and 86. Note that the wall of the trachea and the bronchi (the two main branches of the trachea) are supported by rings or "hoops" of cartilage. Are the hoops complete rings? This can best be determined by a study of a cross section of the trachea with the microscope. In this section note also the lining of the trachea, which consists of epithelial cells like those pictured in Ritchie, Fig. 6. The cilia will probably be visible on these cells, but with difficulty.

Notes: Sketch a cross section of the trachea as it appears under the microscope.

EXERCISE 61. LUNG CAPACITY. (CLASS WORK)

Apparatus: A spirometer. This instrument is commonly used in gymnasiums for measuring lung capacity. If this is not available, use the apparatus shown in Fig. 16. It consists of a large bottle having a capacity of one gallon (231 cubic inches, or 4500 c.c.), which is large enough for the use

of high school pupils; a large shallow pan capable of holding about two gallons of water; a rubber tube; bent glass tube through which to blow air into the bottle; a vessel of disinfectant.

Procedure: If a spirometer is available, proceed at once with its use. If the bottle is to be used, fill it full of water and invert it in the pan containing a small quantity of water.



FIG. 16. Bottle used as a spirometer. The bottle is filled with water and inverted without loss of contents into a vessel of water. The volume of water displaced by blowing into the bottle measures the lung capacity.

Leave a space under the mouth of the bottle to receive the end of the tube. The bottle may be tilted and held by one pupil while a classmate makes the test. The end of the tube should be disinfected and washed each time before it is taken into the mouth of another pupil.

When ready, the experimenter takes the deepest inspiration possible. Then, placing one end of the tube in his mouth, he forces the greatest quantity of air out of his lungs into the bottle, thus forcing out the water from the bottle and replacing it with air from the lungs. The volume of air in the bottle may easily be measured. If it fills the gallon bottle $\frac{3}{4}$ full, the capacity of the lungs is $\frac{3}{4}$ of 231 cubic inches, or 173 cubic inches.

To facilitate the reading off of the volume of air in the bottle, a paper strip may be pasted on the outside of the bottle as shown in Fig. 17. On this strip of paper a scale is marked as follows: Set the bottle in an upright position and pour water into it 100 c.c. at a time. On the strip of paper mark the level of the water after each addition and

number the marks representing 100's (up to 4500⁺ c.c.). You now have a scale that can easily be read off. To prevent the paper from coming off when wet, paint over it a film of shellac (10 g. of shellac dissolved in 50 c.c. of alcohol).

The normal lung capacity for a young man 5 ft. 8 in. in height is 225 cu. in., or 3700 c.c. For each inch of stature less than this the capacity is 8 cu. in., or 125 c.c., less.

Notes: Make a record of your lung capacity; calculate what the normal or average lung capacity is for a person of your height. Make a table of these two items for all the pupils of the class and note whether the average of the class is above or below the normal.

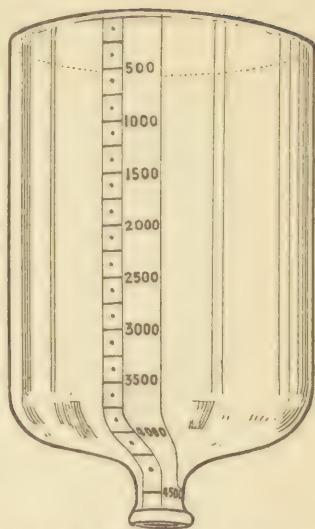


FIG. 17. A scale pasted on the outside of the bottle facilitates reading off the volume of air in the bottle. See Exercise 62 for method of making the scale.

EXERCISE 62. THE SWEEPING ACTION OF THE CILIA. (DEMONSTRATION)

Apparatus and material: A frog; a killing box; chloroform; dissecting instruments; Ringer's solution.

Procedure: Kill a frog with chloroform. Cut off the head, and from this remove the lower jaw. Lay the cranium down, with the palate up, and keep the roof of the mouth moistened with Ringer's solution. Place a very small flake of cork or blotting paper on the posterior edge of the mucous membrane of the mouth (*i.e.* nearest the throat)

and observe that the cork is "swept" forward toward the lips.

Notes: Explain how the flake of cork is swept forward on the mucous membrane of the mouth in this experiment. (See Ritchie, Figs. 3 and 6.)

EXERCISE 63. CHEST EXPANSION. (HOME WORK)

Experiment a. Measuring the chest expansion. (Class work.)

Apparatus: A tape measure.

Procedure: Measure your chest with a tape measure along the line of greatest expansion (9th rib): (1) after greatest possible inhalation; (2) after greatest possible exhalation. The difference is the "chest expansion."

Notes: Make a record of your measurements in this exercise.

Experiment b. Exercise to increase the chest expansion.

Apparatus: A tape measure.

Procedure: By taking proper breathing movements daily it is possible to increase one's chest expansion considerably. Each morning on rising and each night before retiring, a number of deep breaths should be taken, aided by the proper movement of chest, shoulders, and arms. The exercises should be taken out of doors or at an open window. It is a good plan, moreover, to perform the exercises in the classroom between recitations, with the windows thrown open. The following suggestions will prove helpful:

In taking the breathing exercises stand firmly with the weight on the balls of the feet, heels together, toes turned out at a comfortable angle, head up, shoulders and hips back.

Inhale deeply, at the same time rolling the shoulders back

as far as possible and turning the palms of the hands outwards. Raise the elbows to the level of the shoulders, bend the arms at the elbow until the finger tips touch in front of the chest. Throw the arms outwards horizontally, bend back the head and the trunk, and take a long, deep breath. Bring the arms, head, and trunk back to the starting position and exhale forcibly.

Vary the exercise by starting with the hands at the sides. Take a deep breath while gradually raising the arms sidewise to a horizontal position; lower the arms more rapidly and exhale forcibly.

Notes: Measure your chest expansion every two weeks while practicing these exercises, and keep a record of the increase of expansion.

EXERCISE 64. HOW WE BREATHE. (DEMONSTRATION)

Experiment a. Raising and lowering the ribs (chest expansion).

Apparatus and material: Ritchie, Figs. 16, 19, and 32.

Procedure: In Figs. 16 and 19, note that the ribs hang down in front, *i.e.* are lower at the ventral end than at the dorsal. This can be seen in side view of the orangutan, Ritchie, Fig. 32. When one set of muscles between the ribs contracts and raises the ribs and the sternum, the diameter of the chest between the backbone and the sternum (and therefore the capacity of the chest) is increased. When the ribs are depressed, the air is forced out of the lungs because the capacity of the chest is decreased.

Notes: Using Ritchie, Figs. 16, 19, and 32, draw a side view of three ribs with the vertebræ and the sternum to which they are attached. Sketch them first lowered in expiration; then with dotted lines represent them raised in inspiration.

Experiment b. Lowering the diaphragm (abdominal breathing).

Apparatus: The model shown in Fig. 18. If a bell jar with a hole at the top is not available, cut the bottom off a large bottle. This can be done in the following manner: Scratch the bottle with a hard file along the line where it is desired to break it. Soak a string in kerosene oil, and

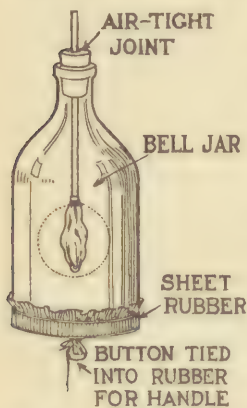


FIG. 18. Model to show the action of the diaphragm in breathing. (See Exercise 63, b.)

wrap it around the bottle over the scratch. Burn the string, and, while the bottle is still hot, immerse it in cold water. The bottom should fall off smoothly. Remove any cutting edge from the bottle with a file. The rubber balloon is such as is sold on whistles (or "squawkers") at circuses. The tube connecting with the balloon is passed through a rubber cork which fits tightly into the mouth of the bottle. A collar button or a marble is tied in a piece of sheet rubber (which may be purchased from a dentist) for a handle. The rubber is tightly fastened to the bottom of the bottle or bell jar with strong

cord. The "handle" should occupy a position in the center as shown. All joints should be air tight. This apparatus, except the sheet rubber and the balloon, may be kept from year to year; these latter deteriorate and soon lose their elasticity.

Procedure: The chest wall, the lungs, the air passages, and the diaphragm of the body are represented in the model by the bottle, the rubber balloon, the tube, and the sheet rubber

respectively. Pull the rubber "diaphragm" by the handle, and observe the inflation of the lungs.

Notes: Describe this experiment, and show how it illustrates the process by which air gets into the lungs in breathing.

EXERCISE 65. ARTIFICIAL RESPIRATION. (CLASS WORK)

Apparatus and material: Ritchie, pages 274-276, and Figs. 132-134; also the Red Cross abridged textbook on First Aid to the Injured. One of the boys in the class should serve as the subject upon whom the method is demonstrated.

Procedure: Follow the directions given in Ritchie for removing water from the lungs, supposing breathing to have ceased on account of drowning and not from suffocation by natural gas, lightning, or other accident. Place at the head of the subject a hot-water bottle or heated stone wrapped in a coat. Warming the head of the patient is said to prevent convulsions. Practice one method in which one operator works and one method in which two work. The methods represented by Ritchie, Figs. 133, *B*, and 134, are probably the best. With one operator at work the pressure is applied to the lowest ribs and is directed forwards as well as downwards. Where two operators are at work as in Fig. 134, one presses against the lower end of the sternum and the arch of the ribs (see Ritchie, Fig. 19), at the same time the other presses the arms of the patient against the chest. Both operators remove the pressure suddenly and at the same time. The arms of the patient are swung around horizontally during inspiration. The two movements should be repeated in unison about fifteen times per minute.

Notes: Write out the methods of artificial respiration as observed; state also other useful treatment of the patient.

EXERCISE 66. NUMBER OF BREATHING MOVEMENTS. (HOME WORK)

Procedure: Count the number of breathing movements per minute in different persons, as indicated by the movements of the chest. Do this without the knowledge of the subject under observation. Count the number of breaths taken by a person after he has been running, as well as after a period of rest.

Notes: Record the results of your observations and explain them.

EXERCISE 67. ANALYSIS OF AIR. (CLASS WORK)

Experiment a. Air needed to support combustion.

Apparatus and material: Those represented in Ritchie, Fig. 79.

Procedure: Perform the experiment as directed, page 161.

Notes: Describe the experiment and explain what happens.

Experiment b. Carbon dioxid will not support combustion.

Apparatus and material: The apparatus shown in Fig. 19 (compare with Fig. 8); pieces of limestone and marble; 10% hydrochloric acid; a jar with a burning candle.

Procedure: The apparatus shown in Fig. 19 is known as a carbon dioxid generator. The gas is driven off the limestone by the acid. Carbon dioxid need not be collected under water as in the case of hydrogen for, being much heavier than air, it will flow into a jar like water. The gas may be gathered by simply letting it flow out of the delivery tube into a jar, or tumbler.

Have ready a tumbler to receive the gas and place a lighted candle in a jar at a distance from the generator. Pour the

acid over the limestone, and allow the gas to flow for about ten minutes. Then collect a tumblerful of the gas, and pour

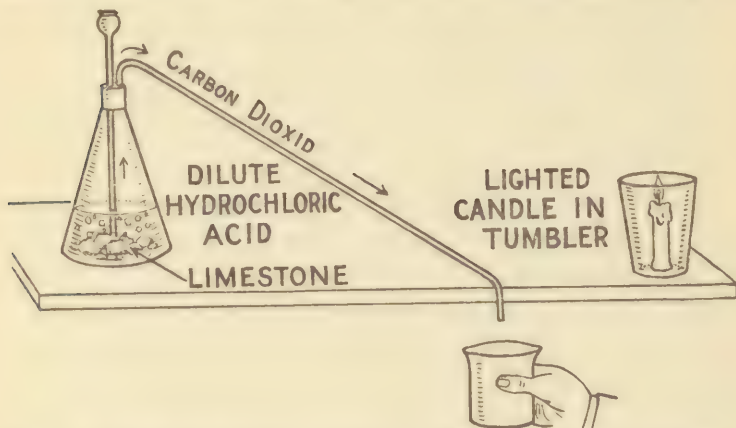


FIG. 19. Carbon dioxide generator. (Compare with Fig. 8.) As carbon dioxide is a heavy gas it may be gathered in a tumbler and poured into another vessel as water is poured.

it over the burning candle. The candle is extinguished at once.

Notes : Describe the properties of carbon dioxide.

Experiment c. Air always contains a trace of CO_2 .

Apparatus and material : A glass of limewater (fresh lime dissolved in water); a glass tube bent at one end; an aspirator bulb.

Procedure : Filter the limewater so as to get it perfectly clear. Pump air through the glass of limewater with the aspirator bulb. After a time the limewater will become cloudy, indicating absorption of CO_2 from the air.

Notes : Write up this experiment, sketching the apparatus used.

Experiment d. Oxygen makes up about one fifth of the air ; nitrogen four fifths.

Apparatus and material: The apparatus shown in Fig. 20.

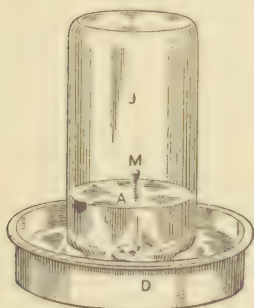


FIG. 20. Apparatus for burning oxygen out of the air in a jar with a match head. *M*, match; *J*, quart jar; *D*, dish of water; *A*, level of water after removal of oxygen by the burning of the match head.

The match is set upright in a flat cork and floated in a shallow pan.

Procedure: Light the floating match and at once invert the jar over the burning match head. The phosphorus of the match head will burn out the oxygen from the jar. The water will rise to replace the oxygen. Measure the distance the water has risen.

Remove the jar and set it upright. Test the remaining gas (nitrogen) in the jar by lowering a burning match into it. Nitrogen will not support combustion.

Notes: Write up this experiment.

EXERCISE 68. CHANGES IN EXPIRED AIR. (CLASS WORK)

Apparatus and material: A tumbler of limewater; glass tubes; thermometer; large jar.

Procedure: To show that expired air contains more CO_2 than inspired air blow the breath through a tumbler of lime water. Compare the result with that obtained in Exercise 67, c.

To show that expired air is warmer than the surrounding atmosphere, blow upon the bulb of a thermometer.

To show that expired air contains considerable moisture, blow upon a window pane or other plate of glass and note the moisture condensed on the glass.

To show that expired air contains organic matter, blow the breath repeatedly into a quart jar that has previously been thoroughly cleaned. Seal the jar and set it in a warm place. Three weeks later smell the contents of the jar. Organic matter from the breath has decomposed.

Notes: Write up each experiment in this exercise.

EXERCISE 69. RESPIRATION IN OTHER ANIMALS. (CLASS
WORK)

Apparatus and material: Earthworms in a shallow dish containing a very little water; an insect such as a grasshopper or a white beetle grub; a goldfish in a glass aquarium; a frog or toad. Beetle grubs such as are found in well-rotted logs are very desirable for study. The toad should be kept in a box containing moist earth covered over with leaves.

Procedure: Study the animals mentioned above with a view to observing how they get their supply of oxygen. An earthworm has neither gills nor lungs, but "breathes" through the skin. Note the blood vessels, which can be seen through the moist, thin skin.

An insect has fewer blood vessels than an earthworm, but it has air tubes which carry the air directly to all parts of the body. The openings to these air tubes may be seen along the sides of a grasshopper and more plainly along the sides of white beetle grubs.

Observe the fish and the toad. Note how each gets a supply of oxygen (Ritchie, page 169).

Notes: Write up your observations on respiration in these animals.

SECTION VIII. VENTILATION

EXERCISE 70. HEATED AIR RISES. (CLASS WORK)

Apparatus and material: A shoe box with two holes cut in it as shown in Fig. 21; a candle; several small rags that have been soaked in saltpeter solution and allowed to dry.



FIG. 21. To show that heated air rises. Two holes are cut in a shoe box; a lighted candle furnishes heat. The current of air is made visible by means of smoke.

Procedure: Place a lighted candle in the shoe box. Demonstrate the "ventilation" of the shoe box brought about by the burning candle. This may be done best by creating a smoke and noting the direction of the air currents. A good cloud of smoke is produced by a smoldering rag which has previously been soaked in saltpeter.

Perform the experiment described in Ritchie, page 181. The room should be well warmed when the experiment is tried, and the wind should not be blowing strongly from the direction of the open doorway.

Notes: Write up the experiments in this exercise.

EXERCISE 71. SYSTEMS OF HEATING AND VENTILATION. (HOME WORK)

Material: The heating and ventilating systems of schools and other public buildings of the community.

Procedure: Study the method by which your school building is heated and ventilated. If the rooms are heated by stoves, are there fresh-air inlets under them and are the stoves supplied with a jacket? Is there a foul-air outlet in connection with the smoke flue? Is there a pan of water on the stove to prevent extreme dryness of the air? Is there an

automatic regulator on the stove? If the building is heated by a furnace, are the rooms supplied with foul-air outlets? Is the air moistened artificially after it passes the furnace? Is there a thermometer on the wall of your schoolroom? Is there also a hygrometer?

Study the means of ventilation of your moving-picture shows and theaters. Are there electric fans in use to force the foul air out and draw the fresh air in? Is the room kept clean or does the dust fly thickly about when people move about in the room?

Notes : Make a record of your observations.

EXERCISE 72. SANITARY LAWS PERTAINING TO VENTILATION.
(HOME WORK)

Material : A copy of the Sanitary Code of your state and the sanitary ordinances of your city. The former may be obtained from the State Health Officer and the latter from the proper city authority.

Procedure : Study the Sanitary Laws with regard to ventilation of schools, playhouses, depots, sleeping cars, and the like. Are the laws obeyed in your city or town?

Notes : Make a list of important sanitary laws that are fairly well obeyed, and a list of those that are entirely neglected.

EXERCISE 73. OPEN-AIR LIVING. (CLASS WORK)

Procedure and notes : Make a study of the screened sleeping porches of your neighborhood and write an essay on the advantages of the screened sleeping porch.

SECTION IX. THE KIDNEYS

EXERCISE 74. THE STRUCTURE OF THE KIDNEY. (CLASS WORK)

Apparatus and material: The kidney of a sheep or ox, obtained from a butcher; a scalpel.

Procedure: Review Exercise 38, b, in which the position of the kidney, ureter, and bladder was pointed out. (See Ritchie, Fig. 90.) Cut a kidney in half lengthwise through its greatest diameter (as shown in Ritchie, Fig. 91, A). The cut surface will show the cortex (near the surface) and the pyramids, as well as the hollow or pelvis, from which the ureter springs. A good preparation should also show the renal vein and the renal artery. (See Ritchie, Fig. 90.) Which of these two blood vessels carries the "purer" blood and why?

Notes: Make a drawing of a longitudinal section of a kidney.

EXERCISE 75. THE MICROSCOPIC STUDY OF THE KIDNEY. (DEMONSTRATION)

Apparatus and material: Microscope; a prepared slide of an injected kidney.

Procedure: Study the section under the microscope. The section should show the renal corpuscles in the color of the injection used. If the animal was injected with blue, the renal corpuscles will appear as blue spots, because a renal corpuscle is a mass of blood capillaries (Fig. 90) surrounded by epithelial tissue. The "pocket" thus formed communicates with a tubule (Fig. 91, B) which carries off the secretion (excretion) into the pelvis. (See the upper right-hand corner of the section represented in Fig. 91, A.) The five pyramids shown in Fig. 91, A, are bundles of tubules; one of the tubules is shown very much enlarged, with its pocket or

“corpuscle,” in Fig. 91, *B*. Every corpuscle with its tubule is comparable to a sweat gland (Fig. 93). Compare Fig. 91, *C*, and Fig. 93, *B*.

Notes: Describe the finer structure of the kidney according to Ritchie, Fig. 91, and state how the parts look under the microscope.

SECTION X. THE SKIN AND THE BODY TEMPERATURE

EXERCISE 76. A STUDY OF RITCHIE, FIGS. 93-96. (HOME WORK)

Material: A copy of Ritchie's *Human Physiology*.

Procedure: Study first the plans of the drawings shown in Figs. 49 and 51. They represent blocks of tissue which are shown in three dimensions like a cube. Note that the "inner surface of the stomach," Fig. 49, *A*, showing mouths of gastric glands, corresponds to Fig. 95, which shows mouths of sweat glands. Figure 51 likewise corresponds to the sweat pores of Fig. 95. Note that Fig. 94 is the upper portion of Fig. 93, the epidermis, more enlarged. Figure 96 shows a hair, which reaches down into the dermis as far as the fatty layer. Note blood vessel at the root of the hair.

Notes: After having made out all the structures in the skin shown in Figs. 93-96, make a single drawing of a "block" of skin about nine times the size (in area) of Fig. 93, embodying all the features of Figs. 93-96. The drawing should be in three dimensions after the manner of Figs. 49 or 51. Figure 93, *A*, widened out, would furnish two sides, Fig. 95 the upper surface of the block. The cells should be drawn somewhat as in Fig. 94. The hair shown in Fig. 96 could be placed in the section beside the sweat gland of Fig. 93, *A*. (See *The Human Body and Its Enemies*, Fig. 161.)

EXERCISE 77. SECTION OF THE SCALP. (DEMONSTRATION)

Apparatus and material: Microscope; a prepared slide of the human scalp.

Procedure: A good slide of the human scalp, studied under the microscope, should show the features pictured above. It is well to have several slides for demonstration under different microscopes at the same time, as one showing a hair, an-

other the cut coil of a sweat gland (as seen in Fig. 93, *C*), a third a pore, etc.

Notes : Sketch a section of the scalp as seen under the microscope.

EXERCISE 78. THE GROWTH OF THE FINGER NAIL. (HOME WORK)

Apparatus and material : A knife.

Procedure : Cut a small notch in a finger nail near the *lunula* (= little moon, from the half-moon-shaped light area at the base of the nail).

Notes : Keep a weekly record of the movements of the notch. State the manner in which the nail grows forward from the root.

EXERCISE 79. HEAT REGULATION OF THE BODY. (CLASS WORK)

Experiment a. Source and distribution of heat.

Procedure : Review Exercise 26, e (2). Review Ritchie, pages 114, 115, 347, and 348.

Exercise the right arm in a warm room. Does the working arm only become warm or is the warmth felt all over the body?

Notes : State the source of heat in the body. Why do we become warmer when we exercise? Discuss the function of the blood as the distributor of heat in the body.

Experiment b. Loss of heat from the body.

Apparatus and material : An incandescent electric light, burning; a lump of beeswax or paraffin; an iron bar, six inches long; a stewpan of water; two thermometers; alcohol; chloroform.

Procedure: The following experiments show how heat is lost by radiation, conduction, and convection and through evaporation.

a. Radiation. Touch a burning incandescent light globe. Heat reaches your hand. The heat passes from the glowing filament to the glass side by radiation, there being no gas within the globe.



FIG. 22. To show the effect of evaporation on temperature. *A*, thermometer with bulb in water: little evaporation. *B*, thermometer with wet rag tied over bulb. The rag is fanned to hasten evaporation.

b. Conduction. In the preceding experiment the heat passes through the glass of the globe by conduction. Place some beeswax or paraffin on the end of the iron bar. Heat the opposite end in a flame. Soon the wax will melt. Explain.

Dry air is a poor conductor of heat. Therefore, ice boxes are built with air spaces between double walls. Woolen or fur clothing is warmer than cotton or linen because it imprisons most air in its meshes.

c. Convection. Boil a little water in a tall vessel. Note that the hot water at the bottom rises to the top. The heat causes convection currents in the water. Review Exercise 70. The candle causes convection currents in the

box. Why do we blow on a hot object to cool it? Objects cool faster by convection. Why is a rubber coat or "slicker" most effective against cold winds?

d. Evaporation. (*a*) Tie a dry handkerchief about one hand and a wet one about the other. Wave the hands in the air. Which feels the cooler? (*b*) Take two thermometers. Place one in a vessel of water. Wet a rag with the same water and tie it about the bulb of the other, as shown in Fig. 22. Fan the thermometers so as to hasten evaporation. Read the temperatures. Which records the lower temperature? (*c*) The more volatile a liquid the more quickly does it cool on evaporation. Pour alcohol, ether, or chloroform on the hand and allow it to evaporate. What is the result?

Notes: Describe each of the four ways by which the body loses heat. Discuss fully the function of sweat.

SECTION XI. THE NERVOUS SYSTEM

EXERCISE 80. DISSECTION OF THE NERVOUS SYSTEM. (DEMONSTRATION)

Apparatus and material: (1) The dissection of a cat's brain used in Exercise 8. If carefully prepared, this is a valuable specimen for demonstration. It can be kept indefinitely in a tall, clear glass jar. It should show the central nervous system on the dorsal side and the sympathetic system on the ventral side. (2) The brain of a sheep for detailed study. Have the butcher remove the brain under your personal direction. The skull should be clamped in a vise and sawn in two with a circular cut. The cut should be made in a horizontal line corresponding to a boy's hat-band. The roof of the skull can thus easily be removed. The brain should then be carefully removed together with the *dura mater*, or tough outer covering. It is well to have ready to hand for purposes of demonstration one entire brain with the nerves attached and several others sectioned in various planes. Soak the brains over night in 1 % formaldehyde and then preserve them in 5 % formaldehyde.

Procedure: The brain, spinal cord, and sympathetic system should be studied in greater detail than was done in Exercise 8.

a. The brain. Distinguish the cerebral hemispheres, the cerebellum, and the medulla. In man the cerebrum is so large as to cover the cerebellum entirely, so that the latter is invisible from above (Ritchie, Fig. 100). In the lower animals the cerebellum projects beyond the posterior border of the cerebrum. The medulla appears like an anterior enlargement of the spinal cord. Note the *pons* (= bridge), a band of fibers extending around the medulla and connecting the two halves of the cerebellum. Press the two halves of the cerebrum apart and note the broad white band of fibers

(the *corpus callosum*) which connects the two halves of the cerebrum. Point this out in Ritchie, Fig. 99.

Cut the brain along the median plane into two exact halves. Viewing the cut surface of the left half, you now see the parts represented in Fig. 99. None of the gray matter of the cerebrum has been cut through; the cerebellum has been sectioned through both the white and the gray matter. Observe the *arbor vitæ* (a section of the cerebellum), so called from the shape of the white matter (*arbor vitæ* = tree of life). Note that the gray matter is on the outside and the white matter on the inside. Make a horizontal section of the cerebrum a little lower than the word "cerebrum" in Fig. 99. The relation of gray and white matter can easily be seen. Note the convolutions of the brain. The gray matter is seen to follow the convolutions.

b. The spinal cord and the sympathetic system. (Demonstration.) The dissection of the spinal cord as directed in Exercise 8 should show the spinal nerves given off, a pair between every two successive vertebræ. The spaces through which the spinal nerves emerge can be seen in Ritchie, Fig. 21, or in any vertebrate skeleton. In the dissection, the processes of the vertebræ and the bony arches covering the spinal cord should be pinched off with a pair of bone forceps piece by piece. Care should be taken not to destroy the cord or the nerves. Note that each spinal nerve has a ganglion. The ganglia can be seen as knots of tissue (in the cat about the size of a pinhead) just outside the *dura mater* of the cord. Careful observation will show that each nerve is made up of two roots and that the ganglion is a part of the dorsal root. (See Ritchie, Fig. 103.)

Notes: Describe the central nervous system, making the appropriate drawings.

EXERCISE 81. REFLEX ACTION IN THE FROG.

(DEMONSTRATION)

Apparatus and material: A frog or toad; chloroform; a killing box; a pithing needle; 10% acetic acid.

Procedure: Pith the brain only of the frog. (See Exercise 50.) Lay the animal on the table. Stretch out the leg. Is it withdrawn? Apply a drop of 10% acetic acid to the hind foot; to the chest; to the side. What is the result in each case?

Now destroy the spinal cord also by pithing it. Repeat the experiments performed before pithing the cord. Does response to stimulus (reflex action) take place? Why not?

Notes: Study Ritchie, Figs. 101 and 104, and write out a complete answer to the question asked above.

EXERCISE 82. REFLEX ACTION IN PUPIL'S BODY. (HOME WORK)

Apparatus and material: Hot water; a bristle; a mirror.

Procedure: *a.* Make a person wink by striking at him.

b. Count your pulse. Now breathe thirty times a minute for three minutes and count the pulse again.

c. Sterilize a bristle in hot water. Let a friend close his eyes. Insert the bristle as far as possible into the nasal cavity. What is the result? It has been suggested that the purpose of this reflex is to prevent insects from entering the nostrils of sleeping persons.

d. Sterilize a bristle. Have the subject open his mouth and sing "Ah!" Touch the throat with the bristle. What is the result? Why does a person sneeze in one case and cough in the other?

e. Hold a mirror before you. Note the size of the pupil of the eye. Close the eyes one minute. Open them sud-

denly and at the same instant notice the size of the pupil. It is larger, but grows smaller at once.

Notes: Give the results obtained in each experiment of this exercise. Define reflex action.

EXERCISE 83. REACTION TIME. (CLASS WORK)

Apparatus and material: A stop watch.

Procedure: Let ten or more pupils and the teacher join hands and form a circle. The teacher should have a stop watch clasped between his right hand and the left hand of the pupil on his right. The teacher then gives the signal by pressing the hand of the pupil to the right and at the same time starts the watch. The first pupil passes the signal on to the pupil at his right by a pressure of the hand and so on around the circle. When the signal reaches the teacher, he stops the watch. The total time required for the signal to travel around the circle divided by the number of persons in the experiment gives the average reaction time for each.

Perform the experiment a second time, reversing the direction.

Notes: Describe the course the nerve impulse travels from the pupil's left hand to his right hand in this experiment.

SECTION XII. THE SPECIAL SENSES

EXERCISE 84. TOUCH. (HOME WORK)

Experiment a. The temperature sense.

Apparatus and material: Two blunt wires.

Procedure: Perform the experiment described in Ritchie, page 248. Determine the warm and the cold spots on a square inch of skin on the lower surface of the wrist. Use warm and cold blunt wires. Mark the warm spots with black ink and the cold spots with red ink.

Notes: Make a diagram on paper of the warm and the cold spots as determined in this experiment.

Experiment b. Delicacy of touch.

Apparatus and material: The apparatus shown in Ritchie, Fig. 115; a bristle fastened to a handle. A straw from a whisk broom may be clamped between the rubber of a lead pencil and the metal sheath, the pencil serving as the handle.

Procedure: (1) Perform the experiment described in Ritchie, page 248. (2) Let the subject close his eyes. Touch different parts of his body with the bristle and determine in which the least pressure of the bristle may be felt.

Notes: Write up these experiments.

EXERCISE 85. DISTINGUISHING BETWEEN TASTE AND SMELL. (CLASS WORK)

Material: Tufts of cotton; slices of potato, apple, onion, and a piece of apple slightly flavored with vanilla.

Procedure: Let the subject stop his nostrils tightly with cotton, open his mouth, and close his eyes. Place on his tongue in succession the slices of potato, apple, and onion, and the piece of apple flavored with vanilla. Can he distinguish the objects? Why do not foods "taste" when a person has a cold?

Notes: Discuss the results of this experiment.

EXERCISE 86. DISSECTION OF THE EAR. (DEMONSTRATION)

Apparatus and material: The head of a cat; 10 % hydrochloric acid; dissecting instruments.

Procedure: With the aid of Ritchie, Fig. 119, distinguish the parts of the human ear. It is quite possible to demonstrate all these by dissection of the ear of a cat.

Note the external auditory canal in the ear of the cat. Cut this away and dissect down to the bottom of the canal, where the tympanic membrane may be seen. Note the "handle" of the hammer attached to the ear drum.

Now cut away the skin and flesh from the skull and soak it in 10 % hydrochloric acid for 48 hours. At the end of that period it will be possible to cut the bone. Open the middle ear, exposing the ear bones (see Ritchie, Fig. 130). The stirrup is found touching the oval opening ("opening for stapes," Fig. 121). By careful dissection it is possible to expose the cochlea and the semicircular canals. Cut away a little of the bone at a time. If the operation is successful, the specimen may be kept in alcohol or formaldehyde.

Notes: Copy Ritchie, Fig. 119.

EXERCISE 87. TESTS FOR HEARING. (CLASS WORK)

Apparatus: A large dollar watch.

Procedure: Choose a quiet room to make the tests. Make all tests under the same conditions. Blindfold the pupil to be tested and let him stop one ear with a finger (cover the finger with a clean cloth). Hold the watch at such a distance that the ticking cannot be heard and gradually bring it nearer to the pupil. Ask him to give a sign as soon as he can hear the ticking. Measure the distance at which the ticking is first audible.

Test the other ear in the same way.

Test all the pupils and find the average distance at which the watch is heard. Seat those having the dullest sense of hearing nearest the teacher's desk.

Notes : Describe the test for hearing here given and make a record of several cases tested.

EXERCISE 88. DISSECTION OF THE EYE. (CLASS WORK)

Experiment a. External features of the human eye. (Home work.)

Apparatus : A mirror.

Procedure : With the aid of a mirror study your own eye and the means of its protection. Observe that it is set back in the orbit of the skull. Note eyebrows, eyelids, eyelashes, iris, "white" of the eye. Note that the eyeball is covered and the eyelid lined with a smooth membrane, the conjunctiva. The conjunctiva is continually moistened with tears or lachrymal fluid from glands of the same name. The tear is removed through the tear duct. (Study Ritchie, Fig. 122.) Find the opening of the tear duct at the summit of a small papilla on the lower eyelid near the inner corner of the eye.

Notes : Sketch the external features of the human eye as observed in the mirror.

Experiment b. Eye of ox or cat.

Apparatus and material : Eyes of oxen ; the head of a cat dissecting instruments.

Procedure : Dissect out the eye of a cat or secure the larger eye of an ox. If the cat's eye is dissected, note the muscles that move the eyeball and the large white optic nerve (cf.

Ritchie, Fig. 123). Remove the eyeball. (Study Ritchie Fig. 124.) Note from the figure that the transparent cornea is continuous with the sclerotic coat and the iris with the choroid coat. The lens is encased in a capsule and is held in place by a ligament attached to radiating ciliary processes. Cut two broad slits, one on each side of the eyeball, so as to verify these points in the specimens.

Cut another eyeball in vertical section at right angles to the section shown in Fig. 124. That is, separate the eyeball into anterior or front half and posterior or back half. The latter would contain the nerve, the former the pupil and lens. Lay the halves down cut side up. In the posterior half the retina covers the entire interior of the eyeball except one spot, the blind spot. This marks the point where the optic nerve leaves the eyeball. Another spot, the yellow spot containing the area of keenest vision, is marked by a notch in Ritchie, Fig. 124.

In the anterior half of the eyeball, study the lens and its manner of suspension by a ligament. Cut the capsule of the lens and remove the lens from it.

Notes : Make a sketch of each half of the eyeball as seen from the inside.

EXERCISE 89. ACCOMMODATION. (HOME WORK)

Experiment a. Accommodation necessary.

Procedure : Hold a finger before the eye in line with a distant object, say a tree. Close the other eye. Focus the attention upon the tree : the finger is out of focus, *i.e.* the image of the finger is blurred. Focus on the finger : the image of the tree is blurred.

Notes : Write up this experiment.

Experiment b. Muscular effort needed for close vision.

Procedure: Repeat experiment a and note carefully that muscular effort is required to pass from far to near vision. The muscles that contract are the ciliary muscles. The lens bulges out by its own elasticity (dotted line, Ritchie, Fig. 129), but the muscles serve to pull the attachment of the suspensory ligament forward so as to give the lens "slack."

Notes: Write up this experiment. Copy Ritchie, Fig. 129, drawing in red the muscles which contract in accommodating the eye for close vision.

Experiment c. Observing the eye in accommodation.

Apparatus and material: A pin stuck upright in the cork of a small bottle; a match mounted in the same manner.

Procedure: Set the bottle with the pin eight inches from the eye of the person acting as the subject of the experiment. At a distance of two yards set the match on a level with the pin. Let the subject first view the match with the right eye only, keeping the pin in line with the match. Let the observer then take a position on the right of and a little behind the subject, and tell him to focus from the match to the pin. While the subject does this let the observer watch the iris of the eye. As the lens bulges out in changing from far vision (looking at the match) to close vision (looking at the pin), it pushes the iris out also. The bulging out of the iris may be observed in the experiment.

Notes: Write up this experiment.

EXERCISE 90. OPTICAL DEFECTS. (CLASS WORK)**Experiment a. Tests of vision.**

Apparatus and material: A number of Snellen's test cards, which may be obtained from a druggist or optician.

Procedure: Test the pupils for far- and near-sightedness according to the directions on the cards.

Experiment b. Astigmatism.

Material: The appropriate figure on Snellen's test cards.

Procedure: Let the pupil look at the parallel lines of the figure with which to test for astigmatism. If any of the lines look indistinct or run together, astigmatism is present.

Notes: Make a record of the optical defects found among the members of your class.

EXERCISE 91. OPTICAL ILLUSIONS. (HOME WORK)

Experiment a. Deception due to habit.

Material: A sheet of stiff writing paper.

Procedure: Roll the paper in the form of a tube about an inch in diameter. With the left eye, look through the tube towards some bright object, such as the sky. Cover the right eye with the right hand. Give close attention to the tube and incidental attention to the hand. There will seem to be a hole through the hand.

Notes: Write up this experiment.

Experiment b. Other illusions.

Material: Ritchie, Fig. 128; a pair of scissors; an old wall calendar having figures at least one inch high; paste or mucilage; cardboard.

Procedure: Cut out a half dozen figures "8" from the calendar and paste them in a row on a piece of cardboard. Look at the figures right side up and note that the upper loop of the 8 looks almost as large as the lower loop. Turn the card upside down and note the effect. (Letters S cut from adver-

tisements in a newspaper will do as well as figures "8.") (Study also Ritchie, Fig. 128.)

Notes: Write up these experiments.

EXERCISE 92. THE BLIND SPOT. (HOME WORK)

Apparatus and material: A sheet of paper and a pencil.

Procedure: Place a small cross on a sheet of paper and a plain black dot three inches to the right of the cross. Close the left eye and look at the cross with the right eye. Hold the paper about ten inches from the eye. Move the paper farther from or nearer to the eye, always looking at the cross, until the image of the dot disappears.

Review Exercise 88, b. In studying the eye it was observed that there is no retina where the optic nerve penetrates the eyeball to spread over the retina.

Notes: Write up this experiment and show how it proves that there is no retina at the blind spot.

SECTION XIII. THE BACTERIA

EXERCISE 93. FERMENTATION AND DECAY. (CLASS WORK)

Suggestion: The preparation of the cultures described in this exercise may be assigned to different pupils or groups of pupils. The teacher may mount specimens from each culture for study under the microscope.

Experiment a. Yeast.

Apparatus and material: The apparatus used in Exercise 3, b, Fig. 2.

Procedure: Set aside the culture in a warm place and await results. The liquid in the bottle will be displaced by a gas, CO_2 , produced by fermentation of the sugar in the molasses. The sugar of the molasses is attacked by digestive enzymes produced by the yeast cells and broken down into alcohol, acid, and CO_2 . The CO_2 escapes as a gas (note the bubbles) and fills the inverted jar. Taste the fermenting solution: it is sour from the acid. Smell the solution: you can detect the odor of alcohol. Remove the jar and lower a lighted match into it: the match is extinguished. (Compare Exercise 3, b.) Study the yeast plants under the microscope as in Exercise 3, b.

Notes: Describe the manufacture of alcohol, of vinegar, and of cider. What causes light bread to rise?

Experiment b. Bacteria in milk and vinegar.

Apparatus and material: A small quantity of mother of vinegar (dregs from the bottom of apple or wine vinegar); a small quantity of sour milk; microscope; slides and cover glasses.

Procedure: Study the bacteria of vinegar and of milk under the high power of the microscope. The bacteria can be seen more plainly under an oil-immersion lens, which

should be used if available. The bacteria are much smaller than the oil globules of milk and are seen to be in an active, vibrating motion. In both the vinegar and the milk they are of the rod-shaped kind called bacilli (Ritchie, Fig. 141, A). In studying the living bacteria care should be taken to regulate the light which passes through the diaphragm of the microscope, as the bacteria are not visible if there is too little or too much light.

Notes: Review Exercise 32, b. Compare the fermentation (souring) of milk with the fermentation of molasses by yeast.

Experiment c. Decay.

Material: A piece of decaying meat; slides and cover glasses; microscope.

Procedure: Mount scrapings from the meat on a slide and note the bacteria.

Notes: Certain bacteria cause decay as others cause fermentation. Putrid odors accompany decay. Decay results from decomposition of proteins, whereas fermentation results from decomposition of carbohydrates, such as starch in dough and sugar in molasses, milk, etc. The products resulting from decaying proteins such as meats, fish, or milk are especially harmful to the body and often produce ptomaine poisoning.

Make a list of foods which one must be especially careful to secure fresh and pure.

Experiment d. To show that fermentation is due to living things.

Apparatus and material: A half-pint bottle of grape juice; a tumbler; a stewpan of water.

Procedure: Open the bottle of grape juice. Pour out half the contents into the tumbler, which should be left uncovered. Recork the bottle containing the remainder of the grape

juice and heat it for fifteen minutes in water boiled in a stewpan. Set both the open tumbler and the closed bottle in a warm place and await results.

Notes: Explain the results of this experiment.

Experiment e. Hay infusion.

Apparatus and material: A handful of hay; stewpan of water; microscope; slides and cover glasses.

Procedure: Prepare a hay infusion or hay "tea" as follows: Chop a handful of hay into small pieces and steep them in boiling water. Set the infusion aside in a warm place; then study the bacteria that appear in it.

Notes: What do the bacteria live on in the hay infusion? Where do you now think bacteria are found in nature?

Experiment f. Infusion of algæ.

Apparatus and material: Microscope; slides and cover glasses; an aquarium or other vessel filled with water algæ, such as pond scum (*Spirogyra*) or Rockwort (*Chara*). The pond scum is found on the surface of quiet ponds or puddles, is light green in color, and slimy to the touch. Rockwort is found at the bottom of large bodies of clear water, such as lakes or large "tanks." Other submerged water plants will also do for this experiment. The vessel should be overstocked so that the plants will die and decay.

Procedure: Set the infusion of algæ aside in a warm place until decay sets in. Study a drop of water from the culture. Among the bacteria certain larger specimens should be visible which swim through the water with a spiral motion. These bacteria are called spirilla (Ritchie, Fig. 141, C).

Notes: Sketch several spirilla and describe their movements as seen under the microscope.

EXERCISE 94. STAINING BACTERIA. (DEMONSTRATION)

Experiment a. General.

Apparatus and material: Slides and cover glasses; a clean, soft rag; 10 % hydrochloric acid; alcohol; distilled water; methylene-blue stain; alcohol lamp or Bunsen burner; microscope; platinum loop or glass rod.

Procedure: Clean several dozen cover glasses successively with 10 % hydrochloric acid, water, and strong alcohol. Rub them dry and warm them gently in a flame. (It is advisable to have a good supply of clean cover glasses for future use in experimenting, as no cover glass can be used a second time.)

Place a drop of the medium containing the bacteria on a cover glass and spread it evenly over the surface. A platinum wire with a loop at the end is the best thing to use in transferring bacteria. The wire should be sterilized each time by holding it in a flame. A glass rod, rounded at the end by holding it in a hot flame, will serve very well; it should also be sterilized in the same manner. The end of the rod or looped wire is immersed in the liquid and the drop adhering to it is placed on the cover glass and spread over it. The preparation is then allowed to dry. There is now a film of bacteria adhering to the cover glass.

When dry, the bacteria are further "fixed" by passing the cover glass, film side up, slowly through a flame, care being taken to warm the cover glass thoroughly, but not to scorch the bacteria. Hold the cover glass in a pair of forceps while heating, and test its temperature by applying it to the back of the hand; it should not be hot enough to cause pain.

After fixing, the preparation is ready to stain. Hold the cover glass in a pair of forceps, film side up. Care should be taken to remember which is the film side, as it may be hard

to distinguish the two sides after staining. With a glass rod (used for this purpose only) transfer to the cover glass one or more drops of methylene-blue stain, spreading it evenly over the film. Leave the stain on for one minute; then wash it off with distilled water. If stained too dark, leave the stain on a shorter period of time when staining the next specimen. The slide may now be laid on a piece of blotting paper and allowed to dry.

To study the preparation with the microscope, the cover glass is mounted on a glass slide, film side down, either in a drop of water or a drop of Canada balsam, according as a temporary or a permanent preparation is desired. The bacteria may first be studied in water, so as to avoid getting fresh balsam on the objective of the microscope. If the preparation is a good one, the cover glass may be dried a second time and then mounted in balsam. Prepared slides may be kept from year to year, but several preparations should be made in the presence of the class.

Suggestion: For practice in staining the bacteria, perhaps the best material to begin with is that scraped from the teeth. With a clean sterilized scalpel, scrape some of the "fur" from the teeth and spread it over a cover glass. Dilute it slightly with a drop of saliva if necessary. Fix and stain it as directed above. Various kinds of bacteria will be seen. (See **b**, below.)

Notes: Describe the manner of preparing bacteria so that they may be better studied than in the living state.

Experiment b. The three classes of bacteria.

Apparatus and material: Those needed for staining bacteria (**a**, above); specimens from cultures described in Exercise 93. These furnish bacilli and spirilla (Ritchie, Fig. 141); a

stained slide showing bacteria from the mouth; "pus" from a festering sore, boil, or pimple.

Procedure: Fix and stain bacteria as directed. Study bacilli and spirilla as in Exercise 93, except that they should be stained. The bacteria of the teeth are of various kinds, including bacilli, spirilla, and cocci. The cocci (Ritchie, Fig. 141) are rounded bacteria grouped irregularly and in chains. Such cocci are especially common in pus-forming bacteria common in boils and pimples. (See Ritchie, Fig. 145, *B* and *C*.)

Notes: Sketch various groups of cocci.

EXERCISE 95. THE PREPARATION OF SPECIAL CULTURE MEDIA. (DEMONSTRATION)

Suggestion: Several culture media have been described in Exercise 93. For special purposes, however, one of the two culture media here described will be found indispensable. The potato is easier to manipulate, while the agar is more satisfactory for most purposes.

The only difficulty which the teacher will experience in carrying out this exercise lies in the sterilization by heat of the culture media and the dishes. But this difficulty is not insurmountable and the time, patience, and care required will be amply repaid by the highly instructive and enlightening character of the experiments.

Lack of more expensive and convenient apparatus need not deter the teacher from undertaking the experiments here given as the cheaper and more readily available substitutes will suffice. Go over lists of apparatus carefully.

The greater part of the work in preparing the culture media will, of course, fall upon the teacher; but the pupils may help in the routine work. A part of two Saturdays will suffice to get the culture media ready.

Experiment a. How to sterilize the dishes.

Apparatus and material: Twenty Petri dishes (Fig. 24) or flat bottles which it is desired to sterilize; cotton for plugs in the bottles, if these are used; hot-air sterilizer, or the oven of a gas stove or gasoline stove, or the ordinary kitchen oven. (If the potato culture only is used, the dishes need not be sterilized.)

Procedure: Wash out the Petri dishes or the bottles thoroughly and allow them to dry perfectly. When perfectly dry wrap each dish or bottle in a piece of newspaper. (If bottles are used, they should first be tightly stoppered with cotton plugs, made by rolling the cotton into a firm, round mass just small enough to fit the neck of the bottle tightly, Fig. 27.) If a hot-air sterilizer is available, heat the dishes or bottles for twenty minutes at 160° C. (320° F.). The oven of a gas or gasoline stove will, however, serve admirably as a hot-air sterilizer, should the special apparatus with thermometer not be available. Place the wrapped dishes in the oven. Place on the dishes a small piece of bread. When the heat rises to a point at which the bread begins to brown, turn the flame somewhat down and keep the oven at a temperature a little below that of baking for one half-hour. When looking into the oven, open the door very slightly. At the end of a half-hour turn out the flame but do not open the door of the oven until the glass dishes have cooled.

Experiment b. Sterilizing the culture media.

Apparatus and material: The culture media in Petri dishes, tumblers, or flasks, prepared as described below; Arnold sterilizer (Fig. 23) or a canning apparatus.

Procedure: To kill all trace of life in a culture medium, merely bringing it to boiling temperature (100° C. or 212° F.)

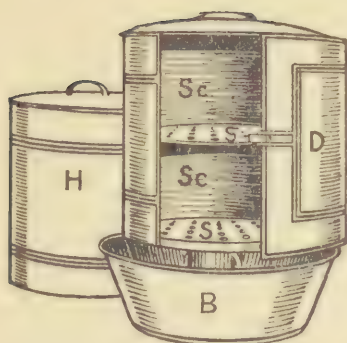


FIG. 23. Arnold steam sterilizer. Water is poured in the bottom *B*. The objects to be sterilized are placed on the shelves *S*, the door is closed, and the whole covered over by the hood; *Sc*, sterilizing chamber.

once is not sufficient. If an Arnold sterilizer is used, the medium is steamed for twenty minutes on three consecutive days, being kept in a warm room between sterilizations to start the spores into growth. Place water in the pan of the Arnold sterilizer and the vessels containing the medium on the shelves. On boiling the water the steam will rise throughout the apparatus.

The canning apparatus will be found more convenient than the Arnold sterilizer as only one heating at fifteen pounds pressure (120° C. or 248° F.) is necessary to kill bacteria. A temperature greater than 100° C. (212° F.) can be attained only under pressure. Heat the medium for ten to fifteen minutes with fifteen pounds pressure in the canning apparatus.

Experiment c. Preparation of potato medium.

Apparatus and material: Petri dishes or glass tumblers; large potatoes (larger if Petri dishes are used); sterilizing apparatus (see b, above).

Procedure: Peel several large potatoes and boil them until they are soft, yet firm enough to slice. With a clean knife cut about twenty slices one fourth of an inch thick, and place

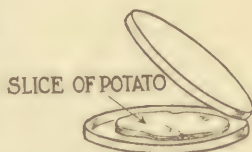


FIG. 24. A Petri dish, for raising cultures of bacteria on nutrient media.

them in the Petri dishes or glass tumblers (Figs. 24 and 25). If tumblers are used, the slice should fit snugly in the bottom of each tumbler. The Petri dishes are merely covered with the lid, but the tumblers should be covered with a layer of cotton tied tightly over the top by means of a strong cord. Tie the cord in a bow-knot so that the tumbler may be readily opened later for inoculation.

When once sterilized, the dishes should, of course, not be uncovered until the operator is ready to inoculate the culture medium.

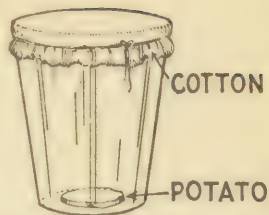


FIG. 25. Tumbler with thick sheet of cotton tied tightly over the top—a good substitute for Petri dishes for potato medium.

Experiment d. Preparation of nutrient agar medium.

Suggestion: Agar is here recommended in preference to gelatine because it remains stiff at ordinary room temperature or even at a higher temperature. This simple culture medium may be prepared in the laboratory or in the home kitchen. The preparation merely consists in cooking nutrient matter under carefully controlled conditions. This medium is in many respects more satisfactory than the potato medium.

Apparatus and material: A clean stewpan, containing 1100 c.c. of water; 15 g. of agar; 3 g. of Liebig's extract of beef; 10 g. of Witte's pepton; white of one egg, well beaten; Erlenmeyer flask of 1250 c.c. capacity; a large funnel; a piece of wire gauze (screen wire cut into a disk about the size of a dollar); a large sheet of absorbent cotton to fit into the funnel; a sterilizing apparatus (see b, above).

Procedure: Heat the pan of water. Cut pieces of agar 2 or 3 inches long, shred them, and dissolve them in the hot

water. Boil the mixture gently and keep it stirred. When the agar is fully dissolved, add the beef extract and the pepton. Allow the mixture to cool so that the sides of the vessel may be touched with the fingers for a second. Then add the beaten white of an egg while stirring the liquids. Bring the liquid to a boil again and boil it from ten to fifteen

minutes, stirring constantly, or better, heat it in the steam sterilizer for a half-hour. It must be thoroughly heated to coagulate all the albumin.

Filter the solution while hot. To do this place the cotton over the funnel and press it down gently into the bottom of the funnel. Then wet the cotton with boiling water and pour in the hot agar, using care not to break the cotton at any point (Fig. 26).

(Caution: The cotton should be supported with the disk of wire gauze placed in the bottom of the funnel, and a small bunch of cotton should be laid in the mouth of the stem of the funnel.) Catch the filtered solution (which should now be clear) in

the Erlenmeyer flask, taking care not to get any of the solution on the mouth of the flask. Roll a mass of cotton into a firm stopper and fit it tightly into the mouth of the flask.

The medium in the flask is now ready to be sterilized as directed in *b* above. After sterilization, the medium may be set aside and may be kept indefinitely. If ready at this juncture to pour the dishes, this should be done at once, as it will save remelting the agar later.

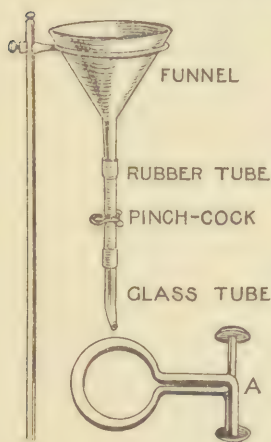


FIG. 26. Funnel arranged for running agar into test tubes or bottles. A, pinch cock attachment.

EXERCISE 96. POURING AND INOCULATION OF DISHES OR BOTTLES. (CLASS WORK)

Apparatus and material: The nutrient agar prepared as directed above; a stewpan with water, large enough to boil the flask of agar medium; 16 of the sterilized Petri dishes or bottles; a small sample of the milk and the water to be tested; a sample of washings from a drinking cup (the edge

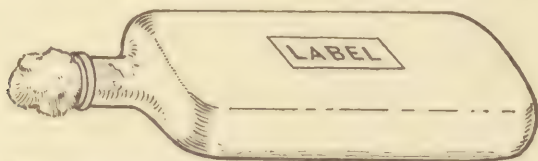


FIG. 27. A flat bottle which may be used instead of Petri dishes for agar. The mouth of the bottle is closed with a tightly rolled plug of cotton.

of a drinking cup is washed with a little water and a sample of this is used in the experiment); pipette or eye dropper; 5 % carbolic acid; 16 labels.

Procedure: Place the Petri dishes or bottles in a row near the edge of the table. If bottles are used, lay them on the flat side, using them like Petri dishes. Write on labels one of the following legends and place the labels each on its own bottle:

- (a) Bacteria in water.
- (b) Bacteria from milk.
- (c) Bacteria from drinking cup.
- (d) Bacteria from finger nails.
- (e) Bacteria from teeth.
- (f) Bacteria from breath.
- (g) Bacteria from air of a clean room.
- (h) Bacteria from a dusty room.
- (i) Bacteria from open air.
- (j) Bacteria from schoolroom.

- (*k*) Fly's promenade.
- (*l*) Bacteria drying.
- (*m*) Bacteria from air — compare with (*n*).
- (*n*) Bacteria on ice — compare with (*m*).
- (*o*) Bacteria and light — compare with (*m*).
- (*p*) Bacteria and carbolic acid.

Into (*a*) place 2 c.c. of the sample of water; into (*b*) place 1 c.c. of milk; into (*c*) place 1 c.c. of washings from the drinking cup; into (*p*) place 10 c.c. of 5% carbolic acid. Measure the liquid with an ordinary pipette or eye dropper sterilized each time before using.

All the dishes (or bottles) are now ready for pouring and inoculation (*a*, *b*, and *c* are already inoculated).

If the agar has been allowed to solidify in the flask, it must be melted by heating. Boil the flask in a stewpan of water until the agar is thoroughly liquid. Allow it to cool until the flask can be handled with comfort. Do not pour dishes (*a*), (*b*), and (*c*) at this time. As the flask is heavy an assistant should aid in the pouring of the dishes. Let the assistant raise one edge of the dish and hold it in that position until agar has been poured into the dish to the depth of one sixth to one fifth inch. The assistant then lowers the lid (which should, of course, not be raised again except to inoculate the agar). If bottles are used, remove the cotton stopper, pour agar into the bottle, and then lay the bottle on its side again. While the agar is still liquid, the dish or bottle is tilted back and forth until the agar completely covers the bottom of the dish (or flat side of the bottle). Each dish or bottle, (*d*)-(*p*), is poured in this way. Dish (or bottle) (*p*) should have the agar and the carbolic acid solution thoroughly mixed.

Now allow the agar in the flask to cool until one can just endure having the flask held to the cheek. The agar will

still be liquid at this temperature. Now pour dishes (or bottles) (*a*), (*b*), and (*c*), mixing the water or milk and the agar thoroughly.

Dishes (*a*), (*b*), and (*c*) are now ready to set aside.

The pupils may be assigned the dishes for inoculation according to the directions given below. Care should be taken to inoculate each dish after the manner indicated by the label on the dish. After each inoculation, replace the lid (or the plug of the bottle).

Reference will be made below only to Petri dishes, it being understood that if bottles are used in place of the dishes, as nearly as possible the same method will be used in inoculating the bottles as is recommended for the dishes. On account of the small size of the mouth of the bottle exposure to the air should be five times as long for the bottles as for the dishes.

Bacteria from the finger nails (*d*). Clean the finger nails with a toothpick (which may first be sterilized by scorching slightly) and run the infected toothpick in a streak over the agar of the Petri dish (*d*). (A longer stick will be needed to inoculate the bottle.)

Bacteria from the teeth (*e*). Rub another sterilized toothpick (or longer stick) over the teeth to collect bacteria. Inoculate the agar of Petri dish (*e*) as before.

Bacteria in the breath (*f*). Blow or cough over the sterile agar of Petri dish (*f*); then close the dish at once.

Bacteria from the air (*g*). Remove the lid from the sterilized Petri dish (*g*) and expose the agar to the air of a clean living room for five minutes.

Bacteria from dust (*h*). Sweep the floor with a broom and expose Petri dish (*h*) to the air and dust for five minutes.

Bacteria from the open air (*i*). Expose dish (*i*) to the air out of doors for five minutes.

Bacteria from schoolroom (*j*). Expose sterile dish (*j*) to the air of the schoolroom after this has been occupied for some hours.

Flies and bacteria (*k*). Capture a housefly in a vial and allow it to crawl out into Petri dish (*k*) by holding the mouth of the vial under the lid of the dish and quickly dropping the lid over the fly when it emerges from the vial. Imprison the fly in the dish until it has walked over the agar several times. Then set the fly free by raising the lid a little on one side. In all these operations care should be exercised to prevent infection of the agar by air-borne bacteria.

Moisture needed by bacteria (*l*). Open Petri dish (*l*) and leave the lid off. The object of this experiment is to test the effect of drying on the growth of bacteria.

Effect of temperature and light (*m*), (*n*), and (*o*). Expose Petri dishes (*m*), (*n*), and (*o*) to the air of a room for five minutes. Replace the lids. Keep (*m*) at ordinary temperatures with the other cultures; place (*n*) on ice at once and keep it cold throughout the experiment; expose (*o*) to the direct rays of the sun as much as possible. Compare (*m*), (*n*), and (*o*) carefully from day to day. A comparison of (*m*) and (*n*) should show the effect of cold on the growth of bacteria; a comparison of (*m*) and (*o*), the effect of light.

Effect of disinfectant (*p*). Expose dish (*p*) to the air of a room for five minutes.

All of the inoculated Petri dishes (except (*n*) and (*o*)) are to be set aside in a drawer or other dark place and kept at room temperature.

(If any of the culture medium is left over in the flask and

if it is desired to keep it for further experiments, it must be sterilized again, since it has doubtless become infected from the air during the large number of pourings that have been made.)

Another method of procedure is to pour the agar into small bottles or test tubes (enough in each to make one plate) immediately after filtering. These are then stoppered with cotton and sterilized, and, when wanted for plating, the agar, can be melted by setting the test tubes in hot water. In case flat bottles are used for plating, the agar can be run directly into them and sterilized in the bottles. In making plates of water, milk, etc., in Petri dishes, the material can be mixed with the agar in the bottles or test tubes and then poured into the dishes. Follow the directions already given for cooling the agar; for if it is used when too hot, the bacteria will be killed. In case no sterilizer is available these small amounts of media may be rendered sterile by setting them in boiling water for 20 minutes for three successive days.

Notes : Write up the notes as directed in Exercise 98.

EXERCISE 97. INOCULATION OF POTATO CULTURES. (CLASS WORK)

Apparatus and material : Potato culture medium in tumblers; other material, except the culture medium, as in Exercise 96.

Procedure : If potato is used for the culture medium, all the experiments, (a) to (o), outlined above, may be made on this medium without variation except (a), (b), and (c). In these experiments drops of water or milk may be placed on the potato instead of being mixed with it. The results will be found striking, though not quite so satisfactory as with agar.

EXERCISE 98. STUDYING THE CULTURES. (CLASS WORK)

The 16 bacterial cultures, (*a*) to (*p*), inoculated as described above, should now be studied from day to day and careful notes on them kept. Describe exactly what you see. Continue the observations for three or four weeks. In two days colonies of bacteria should be plainly visible. Every particle of dust that falls upon the exposed agar carries one or several bacteria, which soon begin to multiply at the expense of the nutrient agar. One bacterium is invisible to the naked eye; but when one develops into a colony of thousands, they become visible. Each colony is, therefore, a collection of thousands of bacteria. Note the color and shape of the colonies. Note those that grow deep and those that grow on the surface.

EXERCISE 99. QUESTIONS FOR STUDY. (HOME WORK)

The following questions will be found helpful in the study of the cultures. The letters in parentheses refer to the experiment designed to answer the question.

How do we know that living things (bacteria, yeast, etc.) cause fermentation and decay (Exercise 93, *a*)? What do we mean by sterilization? What harmful bacteria are likely to be present in drinking water? (Ritchie, page 328)? How many bacteria did you find in 2 c.c. of water? Can you count them (*a*)? Why is it impossible to get milk absolutely free from bacteria communicated by the milkman (*b*)? How do bacteria get into milk (*g*, *h*, *k*)? Why should the milk vessels be thoroughly scalded? What measures would you recommend to a dairyman to insure clean milk? How may harmful bacteria get into milk (Ritchie, pages 330-331)? How may you catch diphtheria from a public drinking cup (*c*)? Why is it dangerous to scratch a sore with the finger nails (*d*)? Why should the hands be washed with soap and water before each meal? Discuss the care

of the teeth (*e*). Why is it dangerous to pass an apple around so that each person may take a bite (*e*)? How may a consumptive scatter germs (*f*)? How are the common bacteria scattered (*g, h*)? Discuss the dangers of dry sweeping (*h*). Why are carpets not sanitary (*h, i*)? Why are there fewer bacteria out of doors than indoors (*h, j, l, o*)? How do flies carry bacteria (*k*; also Ritchie, Fig. 154)? Why are dark, damp tenements said to "breed disease" (*l, o*)? Why do canned goods "keep" (Exercise 95, a)? Why are refrigerators used (*n*)?



APPARATUS, MATERIAL, FORMULÆ, ETC

APPARATUS

FIRMS FURNISHING LABORATORY SUPPLIES

Bausch and Lomb Optical Company, Rochester, New York.

Microscopes, apparatus, slides, and chemicals.

Spencer Lens Company, Buffalo, New York.

Microscopes, apparatus, slides, and chemicals.

Central Scientific Company, 345 W. Michigan Ave., Chicago, Illinois
Apparatus and chemicals.

L. E. Knott Apparatus Company, Harcourt Street, Boston, Massachusetts. Apparatus, slides, and models.

Kny-Scheerer Company, 225 Fourth Ave., New York City.
Apparatus, slides, and models.

APPARATUS INDISPENSABLE FOR CARRYING OUT THE EXPERIMENTS GIVEN IN THIS MANUAL

One or more compound microscopes, each with two objectives, two eye pieces, double nose piece, iris diaphragm, and Abbé condenser.

One hand lens (on tripod).

One pair of scales or balances, with gram weights up to 100 g. at least.

100 microscopic slides, 25 by 75 mm., medium thickness.

1 oz. of cover glasses, 22 by 22 mm., square, medium thickness.

2 laboratory thermometers, with both Centigrade and Fahrenheit scales.

Apparatus for the "decomposition of water by electrolysis and the collection of gases in separate graduated tubes" (not over \$2.00).
(See Fig. 9.)

Tape measure.

Alcohol lamp.

Aspirator bulb. A bulb from an ordinary aspirator such as is sold in drug stores will do. (See Figs. 15 and 16.)

Rubber balloon or "squawker," probably best secured at a toyshop.
(See Fig. 19.)

Rubber tissue (sheet rubber), $\frac{1}{4}$ square meter (may be purchased from a dentist).

Rubber tubing, pure rubber, elastic.

Diameter 6 mm., 1 meter.

Diameter 10 mm., 3 meters.

Two glass Y-tubes, inside diameter of tubes 5 mm.

Glass tubing (of soft glass, ductile after brief heating).

Inside diameter 3 mm., 1 meter.

Inside diameter 5 mm., 6 meters.

Glass rods, diameter 4 mm., 2 meters. (A glass stirring rod is made of glass rod, cut 8 inches in length and rounded at the ends, by holding in a flame.)

1 dozen pipettes, with rubber bulb, 2 c.c. capacity.

A stewpan.

Iron tripod, height about 240 mm.

3 porcelain evaporating dishes, diameter 100 mm.

1 large funnel, diameter 200 mm.

1 small funnel, diameter 100 mm.

3 thistle tubes. (See 1, Fig. 8.)

2 diffusion shells, of parchment paper, diameter 38 mm., made to slip over bulb of thistle tube.

Erlenmeyer flasks. (See Figs. 8, and 20.)

Four (4) of 250 c.c. capacity.

One (1) of 1000 c.c. or 1250 capacity. (The latter is used for sterilizing agar, Exercise 95, d.)

Rubber stoppers, with two holes, to fit the small Erlenmeyer flasks.

Test tubes (at least 12 for each student), best glass, medium thickness, 160 by 16 mm.

One -halfdozen large test tubes.

2 rubber stoppers, with one hole, to fit the large test tubes. (See Fig. 10.)

1 hacksaw with fine teeth, for sawing bones, etc.

1 flat file, for filing teeth.

1 three-cornered file, for scratching glass. (A glass tube or a glass rod is broken by first scratching the glass on one side and then snapping it in two by pressing gently on the opposite side.)

1 meter parchment tubing for diffusion experiments.

Fine insulated copper wire, 5 meters.

1 roll picture wire.

Absorbent cotton, 1 pound.

Snellen's test cards (may be bought from a druggist or from an optician).

DESIRABLE APPARATUS AND SUGGESTED CHEAPER SUBSTITUTES. (THE SUBSTITUTES, AT LEAST, ARE INDISPENSABLE)

Human skeleton. If the school cannot purchase a skeleton, it may perhaps be able to borrow one from a physician for a few days. If a human skeleton is not available, the skeleton of a cat prepared as directed in Exercise 9, b, will be found very helpful. Dried skulls and other parts of animal skeletons found in the fields should be collected and preserved.

Dissecting instruments. *a.* Bone forceps, a strong scissor-like instrument for cutting bone. A strong pair of scissors is a good substitute. *b.* Scalpel. A highly sharpened pocketknife may be used instead of a scalpel. *c.* A pair of dissecting needles. These may be prepared out of butcher's skewers (rods of hard wood) and large cambric needles. The ends of the skewers are soaked in water over night. The needle is placed in an iron vise, point down, and the skewer is driven on to the needle with a hammer. *d.* Pair of forceps.

Earthenware jar, capacity 5 gallons, with lid, for chloroforming animals. A tight box of convenient size will serve the purpose.

Pithing needle. To make this, mount a large darning needle in a wooden handle, driving the wood on to the point of the needle. Heat the needle red hot in the middle and bend it at an angle of

about 45° . With this the brain and spinal cord of a frog is destroyed. A bent wire may be used.

Section razor, which is hollow ground on one side only. A very sharp knife may be used instead.

Sheet cork, 5 pieces. The sides of a cigar box will do very well instead.

Dissecting board: a simple board, 1 by 2 feet. A screweye should be screwed into each corner of the board. The animal to be dissected is stretched out on the board and its legs are tied to the corners of the board.

Dissecting trays with wax bottoms. These can be purchased complete, but may be made of pans or of pie plates into which a mixture of melted beeswax and paraffin, in the proportion one to four, is poured.

Bell jar, with opening at the top for a cork. A large bottle prepared as directed in Exercise 63 will do as a substitute.

Wide-mouthed bottles, of about 250 c.c. capacity. Empty pickle bottles may be used.

Pneumatic trough, for collecting gases under water. In place of this a tin lid of a candy jar, prepared as directed in Exercise 26, a (1) will be found very convenient. Figure 8 illustrates the use of the lid.

Dollar watch. This may be borrowed.

Stop watch. This may be borrowed from an athletic manager.

Funnel stand. This may be made of wood; for example, of a wooden triangle supported on three legs.

Test tube rack. This may be made of a 2-inch board, 4 by 12 inches. Along one edge a series of holes are bored of such size as to hold a test tube. Along the other edge a row of wooden pegs about 3 inches high (for example, butcher's skewers) are placed 1-1½ inches apart. Test tubes are inverted on these pegs to dry.

Wire test tube holders. Instead of these, strips of paper will serve to hold the test tubes. The sheet of paper is folded into a strip

about $\frac{3}{4}$ inch wide. This is held tightly around the test tube in a way to avoid burning the fingers while heating the test tube over a flame.

Mortar and pestle, for grinding solid chemicals. A piece of hard wood or a piece of sheet iron for a mortar and the head of a hammer for a pestle will work very well.

Spirometer. Instead of this, a bottle, shown in Fig. 18 and used as shown in Fig. 17, is adequate.

Arnold sterilizer. This is a handy apparatus for steaming culture media. A *canning apparatus*, in which culture media may be heated under pressure to a temperature above that of boiling water, is more convenient. Such a canning apparatus can, no doubt, be borrowed by the teacher for a day for the sterilization of the culture media.

Hot-air sterilizer. Where this is not available, the oven of a gas or gasoline stove may be used as directed in Exercise 95, b, care being taken not to get the oven too hot.

Bunsen burner. Where natural gas or gasoline gas is used, Bunsen burners will be at hand. Where no gas is available, a laboratory blowtorch, costing about \$3 or less, will furnish a flame that may be used for heating liquids, bending glass, etc. The vessel containing the liquid may be set on a tripod over the flame. The teacher may learn how to use the blow-torch from a local tinsmith.

Beakers. Six beakers, 250 c.c. capacity (these are of clear, thin glass suitable for heating liquids; they will not break when hot water is poured into them). Cheap tin cups may be used instead for heating liquids (except acids) and ordinary glass tumblers for holding cold liquids.

Petri dishes. Twenty Petri dishes, 100 mm. in diameter, best glass. (These dishes are the best to use for cultures of bacteria; see Fig. 25.) Flat bottles of clear glass, such as one-half pint whisky bottles, Fig. 29 will answer for use with agar culture medium, and glass tumblers (Fig. 25) for use with potato medium.

MICROSCOPIC SLIDES

(c. s. = cross section ; * = least necessary.)

Cartilage	Small intestine (c. s.)
*Connective tissue	Kidney (injected)
*Bone tissue	Skin (scalp, c. s.)
*Striped muscle fibers	Ovary of cat
*Smooth muscle fibers	Eggs of starfish (early cleavage stage)
*Nerve	Hydra (c. s.)
Trachea (c. s.)	Earthworm (c. s.)
Esophagus (c. s.)	*Trichina in pork
Stomach (c. s.)	

BOOKS, BULLETINS, ETC.

Ritchie's *Human Physiology*, World Book Co., Yonkers, New York.

This high school text is referred to in the manual under the designation "Ritchie."

Hartman and Bibb's *The Human Body and Its Enemies* (World Book Co.), a grammar school text on Physiology, Hygiene, and Sanitation.

Martin's *Human Body, Advanced Course* (Henry Holt and Co.), a 550-page college text on physiology ; deals also with Anatomy.

Hough and Sedgwick's *Human Mechanism* (Ginn and Co.), an advanced high school Physiology and Sanitation.

Other textbooks by the World Book Co. on Hygiene and Sanitation will be found of service : *Primer of Hygiene*, by Ritchie and Caldwell ; *Primer of Sanitation*, and *The Primer of Physiology*, by Ritchie ; *The First Book of Health*, by Hartman and Bibb.

The abridged Red Cross textbook on "First Aid," P. Blakiston's Sons Co., 1012 Walnut St., Philadelphia, Pennsylvania.

The Annual Reports of your State Food and Drug Commissioner.

The Bulletins of your State Board of Health.

Your state sanitary laws and city health ordinances.

MATERIAL

SPECIMENS TO BE SECURED FROM THE BUTCHER'S SHOP

Ball-and-socket joint	Brain
Fresh bone (with periosteum)	Eyes
Ribs	Teeth (human teeth may be secured from the dentist's office)
Heart	

CHEMICALS

Acetic acid, glacial	100 c.c.	Salt peter	25 g.
Nitric acid, fuming	100 c.c.	Potassium chloride	25 g.
Hydrochloric acid, concentrated	100 c.c.	Potassium ferrocyanid	25 g.
Sulfuric acid	100 c.c.	Potassium bichromate	25 g.
Chloroform	100 c.c.	Sodium oxalate	25 g.
Alcohol, 95 %	100 c.c.	Calcium oxid (for limewater)	25 g.
Formaldehyde	1000 c.c.	Calcium chlorid	25 g.
Carbolic acid, crystals	25 g.	Sodium chlorid, pure	50 g.
Caustic soda	50 g.	Lumps of zinc	50 g.
Caustic potash	25 g.	Liebig's extract of beef	100 g.
Ammonia, concentrated	250 c.c.	Pepton	25 g.
Copper sulfate	200 g.	Pepsin (Fairchild's)	50 g.
Potassium iodid	25 g.	Eosin	15 g.
Iodine	25 g.	Carmin	25 g.
Potassium chlorate	25 g.	Methyl-green	15 g.
Black oxid of manganese	25 g.	Fuchsin	15 g.
Mercuric oxid	25 g.	Methylene blue	15 g.
Xylol	100 c.c.	Agar	50 g.
Canada balsam	25 c.c.	Rochelle salts	100 g.
Distilled water	—	Wright's stains	25 g.

APPARATUS FOR THE PUPIL

Notebooks; one for recording laboratory notes and one for lectures.

Drawing pencils, hard and medium.

Crayons, at least red, blue, and yellow.

Ruler and eraser.

Dissecting set (if pupil does his own dissecting), including scalpel, scissors, forceps, and pair of needles.

FORMULÆ FOR STAINS AND OTHER SOLUTIONS,

STAINS

Aceto-carmin: Bring a 45 % solution of acetic acid to boiling point and add all the carmine it will dissolve. Filter when cool.

Aceto-methyl green: Water, 100 c.c.; acetic acid, 1 c.c.; methyl-green, 1 g.

Methylene blue:

Solution *A* = 1 g. caustic potash in 10,000 c.c. (10 liters) of water.

Solution *B* = saturated solution of methylene blue in 95 % alcohol.

Add methylene blue to 50 c.c. of alcohol to excess.

To make up the stain: take 70 c.c. of *A* and 30 c.c. of *B*.

Wright's stain for blood: to be secured already prepared from the dealer (25 g.).

SOLUTIONS, ETC.

Iodine solution: 2 g. of potassium iodid are dissolved in 100 c.c. of water; then 1 g. of iodine is added and the solution is well shaken.

Liquid soap mixture:

Soft water	2000 c.c.
Strong ammonia	150 c.c.
Saltpeter	12 g.
Hard soap	75 g.

Fehling's solution:

Solution *A* = 17.32 g. of copper sulfate dissolved in 250 c.c. of distilled water.

Solution *B* = 62.5 g. sodium hydroxid and 86.5 g. of Rochelle salts dissolved in 250 c.c. of distilled water.

For use, mix equal volumes of *A* and *B*. Keep the solutions separate until ready for use.

Agar nutrient culture medium for bacteria. (See Exercise 95, d.)

Ringer's solution :

Water	1000 c.c.
Sodium chlorid	7 g.
Potassium chlorid	0.3 g.
Calcium chlorid	0.25 g.

Normal salt solution :

Water	1000 c.c.
Sodium chlorid	7 g.

How to make a solution of a given per cent of concentration.

- (1) If the chemical is in a liquid form : Take as many c.c. of the chemical as the per cent called for. Use enough water to make 100 c.c. Thus a 2 % solution of acetic acid is made of 2 c.c. of pure acetic acid and 98 c.c. of water ; a 10 % solution of hydrochloric acid is made by adding 10 c.c. of concentrated hydrochloric acid to 90 c.c. of water.
- (2) If the chemical to be dissolved is a solid such as sodium hydroxid, sodium chlorid, etc. Add to 100 c.c. of water the same number of grams of the chemical as the per cent calls for. A 10 % solution of sodium hydroxid is made by dissolving 10 grams of sodium hydroxid in 100 c.c. of water.

THE METRIC SYSTEM AND SOME ENGLISH EQUIVALENTS

THE METRIC SYSTEM

10 millimeters (mm.) = 1 centimeter (cm.).

10 centimeters = 1 decimeter (dm.) = 100 mm.

10 decimeters = 1 meter (m.) = 100 cm. = 1000 mm.

1000 grams (g.) = 1 kilogram (kg.).

1000 cubic centimeters (c.c.) = 1 liter (l.).

1 c.c. of water weighs 1 g.

SOME EQUIVALENTS

1 meter = 39.37 inches.

1 inch = $2\frac{1}{2}$ centimeters.

1 liter = a little less than a quart.

1 gallon = 4.54 liters.

1 gram = $15\frac{1}{2}$ grains.

1 lb. = about $\frac{1}{2}$ kilogram.

0° Centigrade = 32° Fahrenheit (freezing).

100° Centigrade = 212° Fahrenheit (boiling).



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